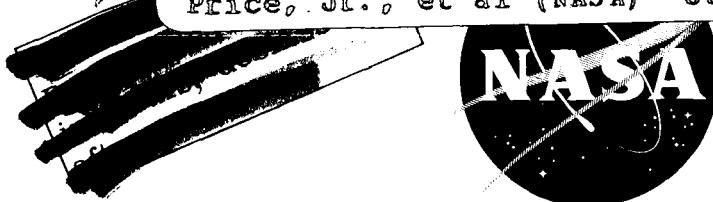


(NASA-TH-X-842) - EFFECT OF HIGHLY SWEPT
FINS ON THE AERODYNAMIC HEATING
DISTRIBUTION ON A FUSELAGE AT MACH NUMBERS
OF 3.51 AND 4.50 AND ANGLES OF ATTACK E.A.
Price, Jr., et al (NASA) Jul. 1963 28 p 00/99 Uncclas
31922



X 63 14554

Order No.

TECHNICAL MEMORANDUM

X-842

EFFECT OF HIGHLY SWEPT FINS ON THE
AERODYNAMIC HEATING DISTRIBUTION ON A FUSELAGE AT
MACH NUMBERS OF 3.51 AND 4.50 AND ANGLES OF ATTACK
FROM 0° TO 16°

By Earl A. Price, Jr., and Robert L. Stallings, Jr.

Langley Research Center
Langley Station, Hampton, Va.

Classification Change
UNCLASSIFIED
By Authority of
16-33-5

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON

July 1963

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL MEMORANDUM X-842

EFFECT OF HIGHLY SWEPT FINS ON THE
AERODYNAMIC HEATING DISTRIBUTION ON A FUSELAGE AT
MACH NUMBERS OF 3.51 AND 4.50 AND ANGLES OF ATTACK
FROM 0° TO 16° *

By Earl A. Price, Jr., and Robert L. Stallings, Jr.

SUMMARY

14554

Heat-transfer measurements have been obtained on a fuselage with four symmetrically spaced highly swept fins through an angle-of-attack range of 0° to 16° at Mach numbers of 3.51 and 4.50. Data were obtained with the model in the 0° roll position and also with the model rolled 22.5° . For comparison purposes both turbulent flat-plate and turbulent swept-cylinder theories are presented for a theoretical stagnation line. The maximum measured heating rates at angles of attack of 8° and 16° were greater than those for turbulent swept-cylinder theory and occurred 32° off the stagnation line.

INTRODUCTION

A problem frequently encountered in the design of supersonic aircraft and missiles is the high skin temperatures resulting from aerodynamic heating. The problem is magnified in regions of shock impingement and other regions of disturbed flow and does not lend itself readily to theoretical solution. This problem is commonly encountered in the area on a fuselage near the juncture of a wing or a fin. Two regions are of particular interest here: (1) the region where the fin bow shock interacts with the fuselage boundary layer, and (2) the fin-fuselage interference region downstream of the fin leading edge. This latter region is the one of particular interest for the present investigation. Methods of predicting turbulent heat-transfer coefficients on flat plates and swept cylinders are presented in references 1 and 2, respectively. The feasibility of applying these theories in regions of disturbed flow is unknown. However, for purposes of comparison, values for a theoretical stagnation line at the same free-stream conditions, are presented for both the theories.

/

SYMBOLS

c	specific heat of model skin, Btu/lb- $^{\circ}$ R
c_p	specific heat of air at constant pressure, Btu/lb- $^{\circ}$ R
g	acceleration due to gravity, ft/sec 2
h	heat-transfer coefficient, Btu/sq ft-sec- $^{\circ}$ R
M	free-stream Mach number
m	limit of index i
n	time limit of integration
N_{St}	Stanton number based on free-stream conditions, $h/\rho_{\infty}V_{\infty}c_p g$
$p_{t,\infty}$	free-stream stagnation pressure, lb/sq ft abs
R	free-stream Reynolds number per foot
t	time, sec
T_e	measured steady-state equilibrium temperature, $^{\circ}$ R
T_t	stagnation temperature, $^{\circ}$ R
T_w	wall temperature, $^{\circ}$ R
$T_{w,n}$	wall temperature at time n, $^{\circ}$ R
$T_{w,0}$	wall temperature at zero time, $^{\circ}$ R
V_{∞}	free-stream velocity, ft/sec
w	weight of skin per unit area, lb/sq ft
x	longitudinal distance along fuselage, in.
y	distance from vertical plane of symmetry, in.
z	distance from horizontal plane of symmetry, in.
α	angle of attack relative to the center line of model, deg
θ	meridian angle, deg

ϕ roll angle, deg

ρ_∞ free-stream density of air, slugs/cu ft

MODEL DESCRIPTION

The model consisted of a fuselage with four symmetrically spaced highly swept fins. The complete configuration was constructed of 0.030-inch Inconel using a "thin-skin" design which minimizes heat sinks and lateral conduction along the skin. In addition the fuselage and fins were insulated from the body support structure and from each other to minimize heat loss by conduction. Details of the insulation technique and geometric characteristics of the model are shown in figure 1. In order to establish the effect of vortex generator size on interference heating, configurations containing no vortex generators, 13° vortex generators, and 18° vortex generators were tested. Iron-constantan thermocouples were located on one-half of the model as shown in figure 2, and their locations are given in table I.

For all tests transition was fixed by a band of number 100 carborundum grit at the nose.

APPARATUS AND TEST CONDITIONS

Tests were conducted in the high Mach number test section of the Langley Unitary Plan wind tunnel. This tunnel described in reference 3 has an asymmetrical sliding block nozzle which permits continuous variation of Mach number from 2.29 to 4.65. The maximum deviation in test-section Mach number is ± 0.05 for Mach numbers of 3.51 and 4.50. The test was conducted through an angle-of-attack range of 0° to 16° at Mach numbers of 3.51 and 4.50 and Reynolds number per foot from 3.34×10^6 to 4.18×10^6 .

METHOD OF HEAT-TRANSFER-DATA REDUCTION

The heat-transfer coefficients were obtained by measuring the transient skin temperature which results from a stepwise increase in stagnation temperature as discussed in reference 4. The following relation, which assumes constant temperature through the skin, negligible lateral heat flow, negligible heat flow to the model interior, and no heat losses due to radiation was used:

$$h = \frac{wc(dT_w/dt)}{T_e - T_w} \quad (1)$$

This equation presented in reference 4 can be written in the following form for complete machine calculation:

$$h = \frac{wc(T_{w,n} - T_{w,o})}{\frac{T_e}{T_t} \sum_0^{m-1} (T_t)_i \Delta t - \sum_0^{m-1} (T_w)_i \Delta t} \quad (2)$$

where i indicates indices of summation and Δt is one-half second. The summations are evaluated over increments of time according to the trapezoidal rule

$$\sum_0^{m-1} (T_t)_i \Delta t = \Delta t \left(\frac{1}{2} T_0 + \frac{1}{2} T_m + T_1 + T_2 + \dots + T_{m-1} \right) \quad (3)$$

and the ratio T_e/T_t is determined experimentally.

RESULTS AND DISCUSSION

A complete listing of all the data obtained is presented in tables II and III. It should be noted that these tables included data obtained for the fins; however, a discussion of this data is beyond the scope of this paper and is presented only to give a complete tabulation of the test data.

The basic configuration was tested with no vortex generators, 13° vortex generators, and 18° vortex generators on the forward portion of the fins as shown in figure 2. The major portion of the investigation was conducted with the 13° vortex generator.

Presented in figure 3 are results obtained for the three vortex generator configurations at three axial stations at $\alpha = 0^\circ$ and $\alpha = 16^\circ$ and $M = 3.51$. The heat-transfer coefficients are presented as a function of the polar angle θ . Since the effect of the vortex generator is seen to be negligible and the variation is within the accuracy of the data, it is believed that limiting the discussion herein to the 13° vortex generator configuration will not result in any loss of generality.

The effect of angle of attack on the fuselage heating distribution for $M = 3.51$ and $M = 4.50$ is presented in figures 4 and 5, respectively. The data are presented as the local heat-transfer coefficient plotted against the polar angle θ for the model rolled 0° and 22.5° . At zero angle of attack, the h distribution indicates relatively low heating rates in the corner regions with somewhat larger values occurring at the two intermediate circumferential stations. These lower heating rates near the fin-fuselage juncture were obtained throughout the range of test variables. It should be noted that the instrumentation located

in this region was at the immediate fin-fuselage juncture. Hence, the lower heating rates in this region could partly be a result of conduction to the cooler model skin under the fins. A thickening of the boundary layer at the corner as a result of the fin and fuselage boundary layers merging could have also resulted thus reducing the local skin friction.

The theoretical heat-transfer coefficient (ref. 1) presented at $\alpha = 0^\circ$ corresponds to a turbulent boundary layer on a flat plate of length equal to the surface length of the model from the nose to each of the individual stations. The local static pressure at the two forward stations was estimated from previous pressure tests obtained on ogive nose cylindrical-afterbody configurations where negative pressure coefficients occur in the region of the nose-cylinder junction and persist downstream for several cylinder diameters. The estimated value of these pressure coefficients for the calculations herein was -0.025 for $M = 3.51$ and -0.01 for $M = 4.50$. The local stagnation pressure was determined from the measured shock angle of the schlieren photographs presented in figure 6 at a location determined from boundary-layer mass-flow considerations. (The shock angles used in these calculations for $\alpha = 0^\circ$ were 26° for $M = 3.51$ and 25° for $M = 4.50$. For $\alpha = 8^\circ$ the shock angles were 30° and 28° for Mach numbers 3.51 and 4.50.)

The theoretical value of h at station 12.75 (fig. 4(a)) is approximately 15 percent greater than the maximum measured values; however, very good agreement is obtained at the two aft stations (figs. 4(b) and 4(c)). The disagreement at station 12.75 is possibly due to the inability to accurately predict the local pressure coefficient and total pressure in this region.

Moving the model to angle of attack resulted in a general increase in the h distribution on the windward side of the model and a decrease on the leeward side. The maximum measured heating rates occurred at $\theta = 148^\circ$ which is 32° off the stagnation line. The theoretical heat-transfer coefficients corresponding to the stagnation line of an infinite swept cylinder with a turbulent boundary layer (ref. 2) are presented along with turbulent flat-plate values (ref. 1) (for $\alpha = 8^\circ$ only) for comparison purposes. The flat-plate calculations with the model at $\alpha = 8^\circ$ are based on modified Newtonian pressures. The heating rates at station 12.75 and station 21.0 are approximately the same in both magnitude and distribution through the angle-of-attack range. The measured distribution at station 28.5 is similar to that obtained at the two forward stations; however, the magnitude of these values is less. These lower values were anticipated, since this station is located in the region where the fuselage is tapered 2.55° . The effect of rolling the model 22.5° was negligible at $\alpha = 0^\circ$ as would be expected. At angle of attack rolling the model resulted in somewhat higher heating rates; the maximum measured value was approximately 25 percent greater than that with the model in the unrolled position. This same trend was noted at all three stations.

The heating distribution at $M = 4.50$ throughout the angle-of-attack range is presented in figure 5. The same general distribution occurs at this Mach number as occurred at $M = 3.51$. The maximum measured heating rates again occurred at $\theta = 148^\circ$. For comparison purposes the turbulent swept-cylinder and flat-plate theories are presented for the stagnation line. The maximum heating rates

are as much as 54 percent greater than those for a theoretical stagnation line. This maximum occurs at $\alpha = 16^\circ$ at station 21.0.

CONCLUDING REMARKS

Heating distributions have been obtained on a fuselage with four symmetrically spaced highly swept fins, through an angle-of-attack range of 0° to 16° . The effect of vortex generators mounted on the forward portion of the fins was found to have negligible effect on the fuselage heating distribution. The maximum measured heating rates were found to occur at $\theta = 148^\circ$, or 32° off the stagnation line. These maximum heating rates are as much as 54 percent greater than turbulent swept-cylinder theory, which occurs at an angle of attack of 16° and a Mach number of 4.50. Data are also presented for the model rolled 22.5° . The maximum measured value at this position was approximately 25 percent greater than that with the model in the unrolled position.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., May 10, 1963.

REFERENCES

1. Sommer, Simon C., and Short, Barbara J.: Free-Flight Measurements of Turbulent-Boundary-Layer Skin Friction in the Presence of Severe Aerodynamic Heating at Mach Numbers From 2.8 to 7.0. NACA TN 3391, 1955.
2. Beckwith, Ivan E., and Gallagher, James J.: Local Heat Transfer and Recovery Temperatures on a Yawed Cylinder at a Mach Number of 4.15 and High Reynolds Numbers. NASA TR R-104, 1961. (Supersedes NASA MEMO 2-27-59L.)
3. Anon.: Manual for Users of the Unitary Plan Wind Tunnel Facilities of the National Advisory Committee for Aeronautics. NACA, 1956.
4. Burbank, Paige B., and Hodge, B. Leon: Distribution of Heat Transfer on a 10° Cone at Angles of Attack From 0° to 15° for Mach Numbers of 2.49 to 4.65 and a Solution to the Heat-Transfer Equation That Permits Complete Machine Calculations. NASA MEMO 6-4-59L, 1959.

TABLE I.- THERMOCOUPLE LOCATIONS

Thermocouple	x, in.	y, in.	z, in.	θ, deg	x, in.	y, in.	z, in.	θ, deg	x, in.	y, in.	z, in.	θ, deg
	No vortex generator				13° vortex generator				18° vortex generator			
1	0.49	0.00	0.00		0.49	0.00	0.00		0.49	0.00	0.00	
2	10.73	1.93	.00		10.67	2.11	.00		10.82	2.32	.00	
3	12.73	.13	1.97		12.60	.13	2.40		12.46	.13	2.65	
4					12.67	.13	2.11		12.58	.13	2.26	
5					12.73	.13	1.84		12.72	.13	1.84	
6									12.72	1.84	.13	
7									12.27	1.84	.13	
8									12.67	2.11	.13	
9	12.72	1.99	.13		12.60	2.38	.13		12.60	2.38	.13	
10	12.70	2.17	.00		12.57	2.54	.00		12.57	2.54	.00	
11	12.72	1.99	-.13		12.60	2.38	-.13		12.60	2.38	-.13	
12					12.67	2.11	-.13		12.67	2.11	-.13	
13					12.73	1.84	-.13		12.73	1.84	-.13	
14									12.72	1.84	-.13	
15					12.73	.13	-1.84		12.73	.13	-1.84	
16									12.67	.13	-2.11	
17	12.73	.13	-1.97		12.60	.13	-2.40		12.60	.13	-2.40	
18	12.75	.18	1.74	5.8	12.75	.18	1.74	5.8	12.75	.18	1.74	5.8
19	12.75	.93	1.48	32.0	12.75	.93	1.48	32.0	12.75	.93	1.48	32.0
20	12.75	1.48	.93	58.0	12.75	1.48	.93	58.0	12.75	1.48	.93	58.0
21	12.75	1.74	.18	84.3	12.75	1.74	.18	84.3	12.75	1.74	.18	84.3
22	12.75	1.74	-.18	95.8	12.75	1.74	-.18	95.8	12.75	1.74	-.18	95.8
23	12.75	1.48	-.93	122.0	12.75	1.48	-.93	122.0	12.75	1.48	-.93	122.0
24	12.75	.93	-1.48	148.0	12.75	.93	-1.48	148.0	12.75	.93	-1.48	148.0
25	12.75	.18	-1.74	174.3	12.75	.18	-1.74	174.3	12.75	.18	-1.74	174.3
26	14.68	2.37	.00		14.68	2.37	.00		14.68	2.37	.00	
27	15.92	2.49	.00		15.92	2.49	.00		15.92	2.49	.00	
28	17.49	1.84	.13		17.49	1.84	.13		17.49	1.84	.13	
29	17.45	2.18	.13		17.45	2.18	.13		17.45	2.18	.13	
30	17.42	2.50	.13		17.42	2.50	.13		17.42	2.50	.13	
31	17.40	2.68	.00		17.40	2.68	.00		17.40	2.68	.00	
32	17.42	2.50	-.13		17.42	2.50	-.13		17.42	2.50	-.13	
33	17.45	2.18	-.13		17.45	2.18	-.13		17.45	2.18	-.13	
34	17.49	1.84	-.13		17.49	1.84	-.13		17.49	1.84	-.13	
35	20.88	.13	2.86		20.88	.13	2.86		20.88	.13	2.86	
36	20.93	.13	2.38		20.93	.13	2.38		20.93	.13	2.38	
37	20.99	.13	1.84		20.99	.13	1.84		20.99	.13	1.84	
38	21.00	.18	1.74	5.8	21.00	.18	1.74	5.8	21.00	.18	1.74	5.8
39	21.00	.93	1.48	32.0	21.00	.93	1.48	32.0	21.00	.93	1.48	32.0
40	21.00	1.48	.93	58.0	21.00	1.48	.93	58.0	21.00	1.48	.93	58.0
41	21.00	1.68	.50	73.5	21.00	1.68	.50	73.5	21.00	1.68	.50	73.5
42	21.23	1.72	.33	79.0	21.23	1.72	.33	79.0	21.23	1.72	.33	79.0
43	21.00	1.74	.18	84.3	21.00	1.74	.18	84.3	21.00	1.74	.18	84.3
44	20.87	1.86	.13		20.87	1.86	.13		20.87	1.86	.13	
45	20.95	2.01	.13		20.95	2.01	.13		20.95	2.01	.13	
46	20.53	2.16	.13		20.53	2.16	.13		20.53	2.16	.13	
47	20.18	2.48	.13		20.18	2.48	.13		20.18	2.48	.13	
48	19.74	2.86	.13		19.74	2.86	.13		19.74	2.86	.13	
49	19.55	3.03	.00		19.55	3.03	.00		19.55	3.03	.00	
50	19.74	2.86	-.13		19.74	2.86	-.13		19.74	2.86	-.13	

TABLE I.- THERMOCOUPLE LOCATIONS - Concluded

Thermocouple	x, in.	y, in.	z, in.	θ, deg	x, in.	y, in.	z, in.	θ, deg	x, in.	y, in.	z, in.	θ, deg
	No vortex generator				13° vortex generator				18° vortex generator			
51	20.18	2.48	-0.13		20.18	2.48	-0.13		20.18	2.48	-0.13	
52	20.53	2.16	-.13		20.53	2.16	-.13		20.53	2.16	-.13	
53	20.87	1.86	-.13		20.87	1.86	-.13		20.87	1.86	-.13	
54	21.00	1.74	-.18	95.8	21.00	1.74	-.18	95.8	21.00	1.74	-.18	95.8
55	21.00	1.48	-.93	122.0	21.00	1.48	-.93	122.0	21.00	1.48	-.93	122.0
56	21.00	.93	-1.48	148.0	21.00	.93	-1.48	148.0	21.00	.93	-1.48	148.0
57	21.00	.18	-1.74	174.3	21.00	.18	-1.74	174.3	21.00	.18	-1.74	174.3
58	20.99	.13	-1.84		20.99	.13	-1.84		20.99	.13	-1.84	
59	20.93	.13	-2.38		20.93	.13	-2.38		20.93	.13	-2.38	
60	20.88	.13	-2.86		20.88	.13	-2.86		20.88	.13	-2.86	
61	24.99	1.76	.13		24.99	1.76	.13		24.99	1.76	.13	
62	24.93	2.31	.13		24.93	2.31	.13		24.93	2.31	.13	
63	24.87	2.85	.13		24.87	2.85	.13		24.87	2.85	.13	
64	24.82	3.32	.13		24.82	3.32	.13		24.82	3.32	.13	
65	24.82	3.32	-.13		24.82	3.32	-.13		24.82	3.32	-.13	
66	24.87	2.85	-.13		24.87	2.85	-.13		24.87	2.85	-.13	
67	24.93	2.31	-.13		24.93	2.31	-.13		24.93	2.31	-.13	
68	24.99	1.76	-.13		24.99	1.76	-.13		24.99	1.76	-.13	
69	28.25	.13	3.73		28.25	.13	3.73		28.25	.13	3.73	
70	28.33	.13	3.03		28.33	.13	3.03		28.33	.13	3.03	
71	28.41	.13	2.33		28.41	.13	2.33		28.41	.13	2.33	
72	24.49	.13	1.63		24.49	.13	1.63		24.49	.13	1.63	
73	28.50	.18	1.52	6.6	28.50	.18	1.52	6.6	28.50	.18	1.52	6.6
74	28.50	.81	1.30	32.0	28.50	.81	1.30	32.0	28.50	.81	1.30	32.0
75	28.50	1.30	.81	58.0	28.50	1.30	.81	58.0	28.50	1.30	.81	58.0
76	28.50	1.52	.18	83.4	28.50	1.52	.18	83.4	28.50	1.52	.18	83.4
77	28.49	1.63	.13		28.49	1.63	.13		28.49	1.63	.13	
78	28.43	2.16	.13		28.43	2.16	.13		28.43	2.16	.13	
79	28.37	2.67	.13		28.37	2.67	.13		28.37	2.67	.13	
80	28.31	3.20	.13		28.31	3.20	.13		28.31	3.20	.13	
81	28.25	3.73	.13		28.25	3.73	.13		28.25	3.73	.13	
82	28.24	3.89	.00		28.24	3.89	.00		28.24	3.89	.00	
83	28.25	3.73	-.13		28.25	3.73	-.13		28.25	3.73	-.13	
84	28.31	3.20	-.13		28.31	3.20	-.13		28.31	3.20	-.13	
85	28.37	2.67	-.13		28.37	2.67	-.13		28.37	2.67	-.13	
86	28.43	2.16	-.13		28.43	2.16	-.13		28.43	2.16	-.13	
87	28.49	1.63	-.13		28.49	1.63	-.13		28.49	1.63	-.13	
88	28.50	1.52	-.18	96.6	28.50	1.52	-.18	96.6	28.50	1.52	-.18	96.6
89	28.50	1.30	-.81	122.0	28.50	1.30	-.81	122.0	28.50	1.30	-.81	122.0
90	28.50	.81	-1.30	148.0	28.50	.81	-1.30	148.0	28.50	.81	-1.30	148.0
91	28.50	.18	-1.52	173.4	28.50	.18	-1.52	173.4	28.50	.18	-1.52	173.4
92	28.49	.13	-1.63		28.49	.13	-1.63		28.49	.13	-1.63	
93	28.41	.13	-2.33		28.41	.13	-2.33		28.41	.13	-2.33	
94	28.33	.13	-3.03		28.33	.13	-3.03		28.33	.13	-3.03	
95	28.25	.13	-3.73		28.25	.13	-3.73		28.25	.13	-3.73	

TABLE II.- HEAT-TRANSFER MEASUREMENTS AT $M = 3.51$ (a) No Vortex Generator; $\phi = 0^\circ$

Thermocouple	T_e/T_t	$T_w, {}^\circ R$	$h, \text{Btu/sq ft-sec-}{}^\circ R$	N_{St}	T_e/T_t	$T_w, {}^\circ R$	$h, \text{Btu/sq ft-sec-}{}^\circ R$	N_{St}	T_e/T_t	$T_w, {}^\circ R$	$h, \text{Btu/sq ft-sec-}{}^\circ R$	N_{St}
$\alpha = 0^\circ; T_t = 719^\circ R; R = 3.34 \times 10^6$												
$\alpha = 8^\circ; T_t = 718^\circ R; R = 3.36 \times 10^6$												
$\alpha = 16^\circ; T_t = 716^\circ R; R = 3.37 \times 10^6$												
1	0.96913	675.2	0.01134	0.002586	0.96541	682.5	0.01335	0.003047	0.96793	679.8	0.01174	0.002670
2	.91637	578.5	.00414	.000944	.90149	566.5	.00442	.001099	.89549	566.5	.00519	.001180
3	.93096	580.5	.00401	.000914	.93060	573.5	.00292	.000566	.91899	565.2	.00317	.000721
4												
5												
6												
7												
8												
9	.93040	578.9	.00389	.000887	.91884	566.5	.00336	.000767	.91224	554.9	.00267	.000607
10	.92555	580.5	.00411	.000937	.91325	575.2	.00475	.001080	.91224	573.2	.00493	.001121
11	.92928	576.2	.00371	.000846	.92052	592.5	.00568	.001296	.91899	606.2	.00690	.001569
12												
13												
14												
15												
16												
17	.92423	573.9	.00365	.000832	.93115	589.2	.00548	.001251	.94431	609.5	.00826	.001879
18	.93489	572.5	.00238	.000543	.94235	572.9	.00164	.000374	.92687	566.2	.00228	.000519
19	.93657	584.9	.00295	.000673	.94515	582.2	.00198	.000452	.93024	559.5	.00099	.000225
20	.93601	579.5	.00348	.000748	.93171	569.5	.00215	.000491	.93024	561.9	.00155	.000553
21	.93601	572.9	.00232	.000529	.92444	563.9	.00217	.000495	.92968	556.5	.00120	.000273
22	.93377	571.9	.00240	.000517	.93171	577.2	.00301	.000687	.93643	585.5	.00374	.000851
23	.93489	578.2	.00326	.000743	.93171	585.2	.00158	.001045	.93306	590.5	.00584	.001328
24	.93657	578.5	.00300	.000705	.92780	587.2	.00531	.001212	.93306	601.9	.00763	.001735
25	.93265	569.5	.00218	.000497	.92836	579.2	.00581	.000870	.93868	595.2	.00378	.001315
26	.92703	582.9	.00432	.000585	.91548	579.2	.00551	.001212	.91393	577.9	.00565	.001285
27	.92198	579.5	.00445	.000992	.91213	575.9	.00532	.001214	.91224	575.2	.00557	.001267
28	.93926	580.5	.00325	.000741	.92724	569.2	.00230	.000525	.93643	565.2	.00107	.000245
29	.92703	579.2	.00400	.000912	.91269	556.2	.00214	.000488	.92068	554.9	.00116	.000264
30	.92555	575.2	.00400	.000912	.91269	559.2	.00502	.000689	.91962	555.5	.00263	.000598
31	.92198	578.2	.00411	.000937	.90877	572.2	.00190	.001118	.91168	573.9	.00549	.001249
32	.92555	574.5	.00387	.000883	.91601	590.2	.00702	.001602	.92349	610.9	.00876	.001992
33	.92423	576.5	.00386	.000880	.92444	596.2	.00730	.001666	.93306	615.2	.01073	.002441
34	.92423	572.2	.00330	.000753	.93227	590.5	.00548	.001251	.94149	605.5	.00737	.001676
35	.92423	575.2	.00409	.000933	.92612	582.9	.00146	.001132	.90381	585.8	.00331	.000753
36	.91918	572.2	.00391	.000892	.91996	573.5	.00392	.000895	.91899	568.5	.00184	.000419
37	.92759	574.9	.00336	.000766	.93395	579.9	.00355	.000810	.91843	559.9	.00193	.000439
38	.93321	569.5	.00227	.000518	.93283	569.9	.00223	.000309	.91956	557.2	.00189	.000430
39	.92872	574.2	.00337	.000769	.93563	573.9	.00246	.000562	.90999	552.2	.00269	.000612
40	.93321	576.9	.00323	.000737	.92323	572.5	.00317	.000724	.91562	546.5	.00078	.00177
41	.93657	578.2	.00301	.000586	.92948	568.9	.00221	.000504	.93587	557.2	.00052	.001118
42	.93994	578.5	.00261	.000595	.93843	570.9	.00180	.001411	.94206	561.5	.00055	.001225
43	.93938	573.9	.00213	.000486	.93955	570.2	.00164	.000374	.94318	565.3	.00092	.00209
44	.93489	578.2	.00330	.000707	.91157	562.9	.00266	.000607	.92518	551.9	.00078	.00177
45	.92647	575.7	.00372	.000848	.90037	556.2	.00280	.000639	.91393	547.9	.00110	.00250
46	.92555	576.9	.00391	.000892	.90032	552.9	.00248	.000566	.90599	547.2	.00123	.00280
47	.92703	580.9	.00427	.000974	.90595	551.2	.00170	.000880	.91056	548.2	.00136	.00309
48	.92567	574.9	.00410	.000935	.91045	556.9	.00270	.000616	.90599	555.9	.00252	.000573
49	.92142	578.2	.00408	.000950	.90709	568.9	.00156	.001041	.90851	569.9	.00315	.001171
50	.92479	571.5	.00388	.000885	.91492	582.5	.00619	.001413	.92237	599.9	.00869	.001967
51	.92423	579.2	.00430	.000981	.92388	595.5	.00742	.001694	.93362	617.5	.01157	.002632
52	.92479	571.5	.00409	.000933	.92720	566.9	.00701	.001600	.93148	615.2	.01031	.002345
53	.92647	574.5	.00338	.000771	.93451	591.5	.00530	.001210	.94318	607.2	.00750	.001706
54	.93828	572.9	.00217	.000495	.914067	581.2	.00283	.000646	.94543	590.2	.00587	.000880
55	.93604	577.1	.00306	.000989	.94179	587.5	.00404	.000922	.95612	603.2	.00575	.001308
56	.93098	574.2	.00315	.000718	.93000	590.5	.00579	.001322	.93981	608.5	.00850	.001933
57	.93208	568.9	.00213	.000486	.93115	577.9	.00351	.000808	.94149	590.9	.00514	.001169
58	.92872	574.2	.00321	.000732	.93115	582.5	.00136	.000995	.94093	596.2	.00605	.001376
59	.92591	578.5	.00419	.000956	.92556	588.9	.00579	.001322	.93137	602.2	.00818	.001861
60	.92555	574.9	.00399	.000910	.92108	578.2	.00513	.001171	.92799	589.5	.00724	.0016147
61	.93208	572.9	.00274	.000625	.90933	557.2	.00247	.000564	.92012	547.9	.00066	.000150
62	.92591	575.2	.00376	.000857	.90037	553.2	.00251	.000580	.89649	560.9	.00159	.000362
63	.92479	579.2	.00447	.001019	.91436	553.9	.00145	.000331	.89593	545.2	.00227	.000516
64	.91974	575.9	.00427	.000974	.91815	561.2	.00277	.000632	.90718	552.2	.00261	.000594
65	.92367	574.2	.00421	.000960	.91269	584.2	.00262	.001429	.91731	584.5	.00793	.001804
66	.92310	571.5	.00436	.000949	.92161	581.5	.00710	.001621	.95081	612.2	.01075	.002445
67	.92567	574.2	.00383	.000873	.92612	592.9	.00666	.001520	.95195	608.5	.00987	.002245
68	.93404	572.5	.00285	.000650	.93675	585.5	.00424	.000668	.94543	598.2	.00582	.001324
69	.92198	574.9	.00431	.000983	.92161	581.9	.00527	.001205	.90212	596.2	.00351	.000753
70	.92251	576.2	.00432	.000989	.91996	571.9	.00372	.000849	.90718	549.5	.00175	.000398
71	.92479	579.2	.00449	.001024	.92780	581.5	.00443	.001011	.91393	553.9	.00155	.000348
72	.92703	569.5	.00270	.000616	.92780	571.2	.00276	.000630	.92743	560.2	.01147	.003334
73	.93601	569.5	.00189	.000431	.92836	567.2	.00209	.000477	.93249	560.9	.0120	.00273
74	.93328	572.5	.00265	.000604	.94046	570.9	.00288	.000657	.92862	560.2	.00160	.00364
75	.93265	572.9	.00263	.000600	.93451	568.9	.00181	.000443	.93756	559.2	.00065	.001148
76	.93657	570.5	.00188	.000429	.93675	568.9	.00162	.000370	.94599	570.2	.01111	.00252
77	.92816	571.2	.00282	.000643	.98640	549.9	.00260	.000593	.92237	550.2	.00067	.000152
78	.92310	571.9	.00351	.000800	.98840	545.2	.00293	.000669	.90043	539.2	.010104	.002384
79	.91974	571.9	.00394	.000898	.89080	541.2	.00179	.000409	.88693	537.2	.00178	.002158
80	.92030	575.5	.00444	.001013	.90129	548.5	.00147	.000336	.89993	542.2	.00179	.00407
81	.92030	572.2	.00416	.000949	.90317	553.5	.00268	.000612	.90506	552.2	.00277	.000630
82	.91637	575.5	.00134	.000990	.89860	561.2	.00140	.001004	.90268	563.2	.00482	.001096
83	.91861	571.9	.00125	.000969	.90541	576.9	.00571	.001303	.91281	588.5	.00740	.001683
84	.91693	573.7	.00139	.001001	.91716	581.5	.00637	.001454	.92714	604.2	.00951	.002163
85	.91918	571.9	.00402	.000917	.92220	588.9	.00654	.001493	.95137	610.2	.01048	.002384
86	.92254	572.2	.00364	.000830	.92556	591.2						

TABLE II.- HEAT-TRANSFER MEASUREMENTS AT $M = 3.51$ - Continued(b) 13° Vortex Generator; $\phi = 0^\circ$

Thermocouple	T_e/T_t	$T_w, {}^\circ R$	$h, \text{Btu}/\text{sq ft-sec-}{}^\circ R$	N_{St}	T_e/T_t	$T_w, {}^\circ R$	$h, \text{Btu}/\text{sq ft-sec-}{}^\circ R$	N_{St}	T_e/T_t	$T_w, {}^\circ R$	$h, \text{Btu}/\text{sq ft-sec-}{}^\circ R$	N_{St}
$\alpha = 0^\circ; T_t = 709^\circ R; R = 3.42 \times 10^6$												
1	0.96976	665.5	0.00974	0.002208	0.96917	673.5	0.01076	0.002436	0.96694	675.5	0.01121	0.002541
2	.90958	571.2	.00496	.001124	.90980	573.9	.00553	.001252	.90824	573.2	.00637	.00144
3	.91841	563.9	.00429	.000972	.91608	560.9	.00397	.000893	.91052	554.5	.00359	.000814
4	.92868	570.2	.00399	.000904	.92521	564.2	.00347	.000786	.92021	556.9	.00292	.000662
5	.92811	570.2	.00381	.000864	.92750	566.2	.00320	.000724	.92534	560.9	.00272	.000616
6												
7	.92868	571.2	.00388	.000880	.91551	559.2	.00312	.000706	.92078	554.5	.00219	.000496
8	.92754	570.9	.00409	.000927	.92407	553.5	.00314	.000711	.91964	554.5	.00231	.000524
9	.91955	564.2	.00422	.000957	.91437	556.9	.00376	.000851	.91736	555.5	.00350	.000793
10	.91499	572.2	.00474	.001074	.9137	573.9	.00502	.001371	.91736	571.2	.00577	.001508
11	.91908	562.2	.00411	.000932	.92122	574.2	.00544	.001232	.92648	588.2	.00701	.001589
12	.92754	569.2	.00389	.000882	.93092	583.9	.00567	.001284	.93332	602.9	.00818	.001854
13	.92697	572.5	.00418	.000948	.93206	585.5	.00575	.001302	.93617	598.2	.00852	.001931
14												
15	.92468	567.2	.00366	.000830	.92407	573.5	.00461	.001044	.92554	579.5	.00588	.001333
16	.92411	566.2	.00374	.000848	.92407	571.9	.00469	.001062	.92477	578.2	.00595	.001348
17	.91727	562.5	.00416	.000943	.91727	567.5	.00512	.001159	.91907	571.9	.00625	.001416
18	.93552	565.9	.00232	.000526	.93777	562.9	.00188	.000426	.93674	561.2	.00165	.000374
19	.93667	572.9	.00318	.000721	.94120	571.5	.00265	.000600	.94301	568.2	.00218	.000494
20	.93724	571.5	.00310	.000703	.93320	567.5	.00287	.000650	.93560	564.9	.00239	.000512
21	.93610	569.2	.00262	.000594	.93092	566.5	.00264	.000598	.92591	556.2	.00203	.000460
22	.93610	566.5	.00237	.000537	.93378	569.2	.00277	.000821	.93503	573.5	.00311	.000705
23	.93667	574.2	.00287	.000651	.93663	580.5	.00356	.000806	.93845	585.5	.00433	.000981
24	.93781	570.9	.00322	.000730	.92978	573.2	.00429	.000971	.92762	577.9	.00555	.001258
25	.93210	568.5	.00237	.000537	.92861	574.2	.00318	.000720	.92933	581.2	.00411	.000931
26	.91384	574.2	.00558	.001259	.91551	567.5	.00187	.00103	.90938	563.2	.00507	.001119
27	.91556	578.9	.00618	.001469	.91665	569.5	.00502	.001371	.90824	561.2	.00489	.001108
28	.93838	573.5	.00343	.000771	.93549	574.2	.00362	.000820	.92135	588.2	.00253	.000573
29	.92811	572.9	.00448	.001016	.92407	569.9	.00397	.000899	.90881	546.5	.00296	.000555
30	.92583	578.2	.00556	.001260	.92065	563.9	.00422	.000955	.90995	549.2	.00315	.000714
31	.92583	581.5	.00589	.001355	.91608	570.5	.00516	.001188	.90767	560.9	.00479	.001086
32	.92011	579.9	.00545	.001255	.91722	577.9	.00569	.001280	.91557	583.5	.00652	.001478
33	.92754	572.5	.00442	.001002	.92065	576.5	.00548	.001241	.92021	583.9	.00750	.001700
34	.92688	567.9	.00345	.000782	.92407	570.5	.00446	.000964	.92477	577.5	.00553	.001253
35	.92697	579.9	.00564	.001278	.92521	579.5	.00577	.001306	.92819	576.5	.00515	.001167
36	.92411	567.5	.00394	.000893	.92236	568.2	.00403	.000912	.92021	565.5	.00410	.000929
37	.93210	568.9	.00332	.000753	.93720	569.2	.00293	.000663	.93671	571.2	.00342	.000775
38	.93495	561.9	.00220	.000499	.93831	560.9	.00180	.000406	.93503	561.5	.00218	.000494
39	.92925	566.5	.00336	.000762	.93035	564.2	.00293	.000665	.93560	564.9	.00261	.000592
40	.93210	568.2	.00330	.000748	.92464	567.5	.00372	.000842	.91622	555.9	.00269	.000610
41	.93552	568.9	.00294	.000666	.92807	568.2	.00355	.000758	.92819	555.9	.00183	.000415
42												
43	.93952	565.2	.00218	.000494	.93549	562.9	.00229	.000518	.93845	561.2	.00190	.000340
44	.93838	571.5	.00311	.000705	.92978	567.5	.00316	.000715	.92762	558.5	.00211	.000478
45	.93210	570.2	.00360	.000816	.92179	565.2	.00355	.000804	.91907	553.9	.00230	.000521
46	.92925	570.2	.00380	.000861	.91893	564.5	.00364	.000824	.91565	551.2	.00225	.000510
47	.93210	575.9	.00452	.001025	.92164	564.9	.00353	.000790	.91964	550.9	.00311	.000431
48	.92811	578.5	.00518	.001174	.92635	566.2	.00386	.000874	.91394	552.2	.00296	.000671
49	.92183	575.9	.00528	.001197	.92007	572.5	.00486	.001100	.90995	561.9	.00468	.001061
50	.92297	574.2	.00515	.001167	.92122	568.5	.00569	.001268	.91565	576.9	.00615	.001394
51	.92640	573.9	.00460	.001042	.92293	578.2	.00559	.001266	.92056	581.9	.00712	.001614
52	.92811	571.5	.00404	.000916	.92521	578.9	.00552	.001204	.92648	586.5	.00682	.001546
53	.93155	568.2	.00321	.000728	.93035	574.5	.00417	.000944	.93589	580.5	.00513	.001163
54	.93724	563.9	.00213	.000483	.93720	566.5	.00237	.000537	.93788	569.9	.00277	.000628
55	.93267	568.2	.00315	.000714	.93149	571.5	.00347	.000786	.94073	576.9	.00400	.000907
56	.93096	566.2	.00310	.000703	.92807	573.5	.00442	.001001	.93104	580.9	.00563	.001276
57	.93495	562.2	.00217	.000492					.93389	578.5	.00348	.000789
58												
59	.93039	572.5	.00427	.000968	.92635	576.9	.00533	.001207	.92420	579.5	.00629	.001426
60	.92811	578.9	.00551	.001249	.90537	569.5	.00648	.001467	.90255	566.2	.00669	.001516
61	.93438	565.2	.00254	.000576	.92007	556.2	.00263	.000595	.90368	542.5	.00218	.000494
62	.92982	568.5	.00360	.000816	.91208	566.9	.00329	.000745	.90207	542.2	.00238	.000539
63	.92982	573.9	.00435	.000868	.92461	561.9	.00298	.000675	.91793	548.2	.00181	.000410
64	.92925	576.9	.00494	.001120	.92807	566.2	.00368	.000833	.92078	555.9	.00294	.000666
65	.92583	572.5	.00474	.001074	.92065	579.5	.00377	.001306	.91511	576.5	.00624	.001414
66	.92583	571.9	.00448	.001016	.92407	577.5	.00361	.001270	.92249	581.2	.00712	.001620
67	.92583	567.5	.00380	.000861	.92407	575.2	.00393	.001139	.92420	583.5	.00676	.001532
68	.93324	564.5	.00265	.000901	.92633	569.2	.00354	.000756	.93589	573.2	.00405	.000918
69	.92925	578.9	.00520	.001179	.92426	570.2	.00550	.001249	.91961	572.2	.00515	.001235
70	.92468	569.2	.00415	.000941	.92326	571.5	.00421	.000953	.92424	586.5	.00443	.000936
71	.92925	574.2	.00458	.001038	.92861	573.5	.00452	.001023	.93047	572.2	.00438	.000993
72	.91513	562.9	.00251	.000569	.93378	565.5	.00251	.000568	.92818	562.9	.00291	.000660
73	.93895	562.2	.00181	.000410	.93838	560.2	.00171	.000387	.92876	558.2	.00221	.000501
74	.93438	565.9	.00268	.000607	.93092	561.2	.00233	.000528	.92477	561.9	.00295	.000669
75	.93495	565.9	.00264	.000598	.93729	562.2	.00278	.000629	.93161	556.5	.00169	.000383
76	.94979	563.2	.00133	.000301	.93891	566.9	.00140	.000317	.93959	556.5	.00126	.000286
77	.93155	563.9	.00271	.000614	.91722	557.9	.00311	.000704	.89229	536.2	.00234	.000530
78	.92811	565.9	.00338	.000766	.90695	556.5	.00371	.000840	.87975	533.5	.00282	.000639
79	.92583	567.5	.00288	.000880	.90523	550.9	.00324	.000731	.89058	532.5	.00192	.000445
80	.92697	569.5	.00275	.000623	.93149	569.9	.00356	.000857	.91052	543.5	.00169	.000383
81	.93210	576.9	.00468	.001061	.91836	557.9	.00337	.000765	.91394	549.5	.00262	.000594
82	.92868	578.9	.00481	.001090	.91208	565.5	.00457	.001035	.90653	556.5	.00140	.000952
83	.92982	574.2	.00445	.001009	.91380	573.2	.00355	.001211	.90995	570.5	.00162	.001274
84	.92126	565.2	.00402	.000911	.91779	571.2	.00517	.001171	.91850	576.9	.00614</td	

TABLE II.- HEAT-TRANSFER MEASUREMENTS AT $M = 3.51$ - Continued(b) 130° Vortex Generator; $\phi = 0^\circ$ - Concluded

Thermocouple	T_e/T_t	$T_w, {}^\circ R$	$h, \text{Btu/sq ft-sec.} {}^\circ R$	N_{St}				
					T_e/T_t	$T_w, {}^\circ R$	$h, \text{Btu/sq ft-sec.} {}^\circ R$	N_{St}
			$\alpha = 120^\circ; T_t = 712^\circ R; R = 3.42 \times 10^6$			$\alpha = 160^\circ; T_t = 712^\circ R; R = 3.41 \times 10^6$		
1	0.96584	677.5	0.01101	0.002490	0.96468	671.5	0.01199	0.002723
2	.90607	582.5	.00609	.001376	.90659	584.2	.00635	.001438
3	.91233	559.2	.00361	.000817	.90602	555.5	.00368	.000836
4	.91859	563.2	.00331	.000749	.91228	551.9	.00292	.000652
5	.91973	562.9	.00304	.000888	.91399	550.9	.00249	.000566
6								
7	.92372	555.2	.00158	.000357	.92652	551.9	.00114	.000259
8	.92201	554.5	.00195	.000441	.92367	549.5	.00144	.000327
9	.91803	558.5	.00357	.000808	.91912	554.5	.00344	.000781
10	.91689	583.9	.00616	.001393	.91741	587.5	.00719	.001633
11	.92770	605.5	.00941	.002129	.93108	616.2	.01117	.002537
12	.93453	613.5	.01054	.002384	.9362	626.2	.01278	.002903
13	.93795	615.2	.01024	.002316	.94418	632.9	.01145	.002601
14								
15	.92713	593.2	.00707	.001599	.93222	597.9	.00864	.001965
16	.92486	591.2	.00730	.001651	.92709	595.5	.00904	.002053
17	.92330	584.5	.00763	.001726	.92310	587.5	.00933	.002119
18	.92258	558.2	.00200	.000552	.91399	549.9	.00187	.000425
19	.92656	555.5	.00154	.000348	.92197	549.9	.00111	.000252
20	.93226	553.9	.00107	.000242	.93150	554.9	.00121	.000275
21	.92599	555.2	.00186	.000421	.93222	554.5	.00153	.000348
22	.93453	581.9	.00140	.000760	.93848	586.9	.00113	.000938
23	.93795	595.2	.00190	.001108	.94019	595.9	.00373	.001302
24	.92656	589.9	.00674	.001525	.92999	593.5	.00822	.001867
25	.93169	595.2	.00148	.001126	.93791	601.2	.00606	.001371
26	.91290	572.5	.00536	.001212	.91912	574.9	.00593	.001347
27	.90835	567.9	.00523	.001183	.91513	570.5	.00575	.001306
28	.92827	556.2	.00163	.000369	.93363	557.2	.00132	.000300
29	.91461	549.9	.00164	.000371	.92426	554.9	.00162	.000368
30	.91063	550.2	.00295	.000667	.91798	557.5	.00311	.000706
31	.90778	566.2	.00493	.001115	.91346	568.9	.00571	.001297
32	.91575	596.8	.00735	.001665	.92197	603.5	.00892	.002026
33	.92372	600.5	.00830	.001877	.92994	612.5	.01041	.002365
34	.93055	591.5	.00653	.001432	.93677	593.9	.00715	.001624
35	.93169	583.2	.00509	.001151	.88836	545.5	.00394	.000895
36	.91575	566.2	.00393	.000889	.91399	542.5	.00108	.000249
37	.93567	572.5	.00319	.000722	.92140	554.2	.00202	.000459
38	.92713	560.2	.00290	.000520	.92140	551.9	.00196	.000445
39	.91006	592.2	.00271	.000613	.90773	543.2	.00194	.000449
40	.90550	541.9	.00152	.000544	.91627	542.2	.00085	.000191
41	.93226	552.2	.00086	.000195	.93620	551.5	.00058	.000132
42								
43	.93966	557.9	.00112	.000253	.94190	559.9	.00102	.000232
44	.92201	549.5	.00147	.000333	.92760	550.2	.00089	.000202
45	.91063	546.9	.00174	.000394	.91969	545.2	.00116	.000265
46	.90721	546.2	.00179	.000405	.91456	544.9	.00142	.000325
47	.91006	544.9	.00178	.000403	.91456	545.5	.00159	.000361
48	.91119	550.5	.00282	.000638	.91285	552.5	.00272	.000618
49	.90778	565.5	.00181	.001088	.91000	564.9	.00528	.001199
50	.91746	588.5	.00655	.001482	.92140	592.2	.00876	.001990
51	.92656	602.9	.00868	.001963	.92994	614.5	.01095	.002487
52	.92941	603.9	.00850	.001923	.93051	611.2	.01001	.002274
53	.93795	594.2	.00599	.001355	.94133	594.9	.00689	.001565
54	.93966	578.5	.00307	.000691	.94304	588.5	.00357	.000811
55	.94478	590.2	.00506	.001145	.94873	592.5	.00596	.001354
56	.93339	596.2	.00707	.001599	.93620	600.2	.00870	.001976
57	.93624	579.9	.00439	.000993				
58								
59	.92149	590.9	.00736	.001665	.92595	592.2	.00880	.001999
60	.91803	586.2	.00774	.001751	.92595	590.5	.00910	.002067
61	.90152	537.9	.00330	.000294	.91342	539.5	.00094	.000214
62	.88273	588.9	.00238	.000538	.89577	588.9	.00220	.000500
63	.89981	540.2	.00191	.000452	.90146	541.5	.00217	.000495
64	.91233	555.5	.00271	.000605	.91285	548.5	.00254	.000577
65	.91461	585.9	.00684	.001547	.91741	594.2	.00810	.001840
66	.92599	600.2	.00870	.001968	.92760	602.2	.01043	.002369
67	.92656	596.5	.00781	.001761	.92766	595.5	.00911	.002069
68	.93966	584.9	.00464	.001050	.94418	589.2	.00558	.001267
69	.90664	567.9	.00521	.001178	.90932	549.9	.00350	.000795
70	.91803	568.5	.00424	.000959	.90260	538.2	.00150	.000341
71	.92941	578.9	.00462	.001045	.90332	539.5	.00189	.000429
72	.92599	561.2	.00246	.000956	.92538	549.5	.00111	.000252
73	.92144	553.2	.00173	.000391	.92424	547.2	.00096	.000218
74	.90835	545.2	.00156	.000553	.91741	545.2	.00108	.000245
75	.92543	546.9	.00076	.000172	.93734	552.9	.00063	.000143
76	.90940	538.5	.00106	.000240	.93450	552.9	.00103	.000234
77	.90607	539.5	.00108	.000244	.92510	544.2	.00067	.000152
78	.89070	537.2	.00205	.000164	.90887	540.5	.00133	.000302
79	.89070	540.9	.00258	.000584	.91057	545.9	.00195	.000443
80	.88924	543.9	.00231	.000523	.91627	547.9	.00177	.000402
81	.90892	550.9	.00293	.000665	.91570	549.9	.00246	.000559
82	.90507	560.5	.00448	.001013	.90830	558.9	.00475	.001074
83	.91176	580.5	.00617	.001396	.91456	589.2	.00751	.001706
84	.92144	592.2	.00795	.001798	.92367	594.9	.00944	.002144
85	.92372	594.5	.00818	.001850	.92420	596.5	.00995	.002260
86	.92770	594.2	.00736	.001665	.92994	596.5	.00902	.002049
87	.93738	585.9	.00508	.001149	.94247	590.5	.00613	.001392
88	.93852	572.9	.00276	.000624	.94475	576.9	.00323	.000734
89	.94136	581.9	.00401	.000907	.94646	586.5	.00503	.001143
90	.93169	585.9	.00509	.001151	.93279	592.5	.00706	.001604
91	.93112	570.9	.00346	.000783	.93450	573.5	.00415	.000943
92	.92543	575.2	.00140	.000995	.92937	579.5	.00531	.001206
93	.91973	579.9	.00623	.001049	.92524	582.5	.00743	.001688
94	.91518	581.9	.00679	.001536	.91627	585.5	.00861	.001956
95	.92372	579.5	.00605	.001368	.92709	581.2	.00713	.001620

TABLE II.- HEAT-TRANSFER MEASUREMENTS AT $M = 3.51$ - Continued(c) 13° Vortex Generator; $\phi = 22.5^\circ$

Thermocouple	Te/Tt	$T_v, {}^\circ R$	h, Btu/sq ft-sec- ${}^\circ R$	N _{St}	Te/Tt	$T_v, {}^\circ R$	h, Btu/sq ft-sec- ${}^\circ R$	N _{St}	Te/Tt	$T_v, {}^\circ R$	h, Btu/sq ft-sec- ${}^\circ R$	N _{St}
1	0.96851	667.8	0.01261	0.002858	0.96633	673.2	0.01359	0.003076	0.96466	675.2	0.02141	0.004875
2	0.90897	569.2	0.00553	0.01253	0.91596	583.5	0.00676	0.01550	0.92078	604.9	0.00962	0.02191
3	0.91870	561.9	0.00453	0.01027	0.91841	570.5	0.00510	0.01154	0.89844	568.2	0.00540	0.01250
4	0.92786	567.9	0.00415	0.00941	0.92697	577.9	0.00516	0.01168	0.89673	560.5	0.00460	0.01048
5	0.92813	569.2	0.00401	0.00909	0.92925	575.5	0.00454	0.01028	0.90084	511.9	0.00301	0.00685
6												
7	.92813	569.2	.00399	.000904	.91784	558.9	.00294	.000665	.92420	558.5	.00298	.000679
8	.92729	568.5	.00414	.000938	.91841	554.5	.00305	.000690	.92363	554.5	.00302	.000688
9	.91985	562.2	.00454	.000984	.91841	559.9	.00411	.000920	.92192	562.9	.00556	.001266
10	.91527	570.9	.00523	.001185	.91784	580.5	.00605	.001369	.92135	605.9	.00994	.002264
11	.91870	559.9	.00421	.000954	.92754	588.2	.00729	.001650	.93446	623.2	.01541	.003509
12	.92729	566.9	.00394	.000893	.91495	588.5	.00823	.001863	.91187	630.2	.01699	.003869
13	.92614	570.5	.00451	.000977	.93667	600.9	.00821	.001858	.91472	633.2	.01680	.003826
14												
15	.92385	565.2	.00386	.000875	.91438	588.9	.00631	.001428	.91301	600.9	.01049	.002389
16	.92328	561.5	.00386	.000875	.93210	588.9	.00677	.001752	.94073	623.5	.01151	.002821
17	.91698	560.2	.00421	.000954	.92411	582.5	.00713	.001614	.93617	617.2	.01103	.002512
18	.93473	564.2	.00245	.000755	.93592	564.9	.00207	.000469	.92363	595.2	.00176	.000401
19	.93598	570.9	.00532	.001750	.94237	570.2	.00250	.000566	.93617	592.9	.00092	.000210
20	.93615	569.2	.00523	.001732	.93210	566.9	.00285	.000645	.92135	592.9	.00213	.000485
21	.93359	566.2	.00268	.000607	.93096	563.5	.00256	.000579	.92876	588.9	.00284	.000647
22	.93473	563.9	.00210	.000514	.93667	577.9	.00357	.000808	.91016	602.2	.00545	.001241
23	.93588	571.9	.00299	.000678	.93929	592.5	.00499	.001121	.94586	624.9	.00829	.001888
24	.93588	567.9	.00330	.000748	.93324	584.5	.00589	.001333	.93674	615.9	.01013	.002307
25	.93072	566.2	.00243	.000551	.93667	589.2	.00424	.000950	.94415	620.9	.00709	.001615
26	.91298	572.9	.00639	.001448	.90985	566.2	.00531	.001202	.91166	585.5	.00745	.001697
27	.91527	577.9	.00693	.001571	.91213	567.9	.00540	.001222	.90767	580.9	.00713	.001624
28	.93874	571.9	.00355	.000805	.92354	561.2	.00279	.000632	.92591	551.9	.00185	.000421
29	.92786	570.9	.00497	.001036	.91327	591.9	.00271	.000613	.91337	547.5	.00196	.000446
30	.92557	576.2	.00580	.001314	.91270	555.9	.00374	.000847	.90995	519.9	.00383	.000872
31	.92500	579.9	.00621	.001407	.90871	567.2	.00515	.001231	.90710	580.5	.00707	.001610
32	.92786	577.9	.00569	.001290	.91384	581.5	.00684	.001548	.91850	609.2	.01084	.002468
33	.92672	570.2	.00460	.001042	.92012	584.2	.00704	.001594	.92819	619.5	.01240	.002824
34	.92845	566.2	.00356	.000807	.92411	578.5	.00558	.001265	.93218	602.5	.00958	.002162
35	.92672	578.5	.00599	.001557	.92185	575.9	.00541	.001225	.86649	545.2	.00492	.001120
36	.92528	565.5	.00404	.000916	.91841	573.9	.00597	.001261	.89351	544.9	.00415	.000940
37	.93187	566.9	.00333	.000755	.93667	576.5	.00418	.000946	.90881	546.9	.00224	.000510
38	.93416	559.5	.00225	.000505	.93724	564.5	.00227	.000514	.93275	557.2	.00165	.000376
39	.92813	564.9	.00348	.000789	.94009	569.2	.00286	.000647	.93161	561.2	.00211	.000480
40	.93130	566.2	.00310	.000771	.92468	570.2	.00406	.000919	.93560	551.5	.00068	.000155
41	.93416	566.5	.00302	.000684	.92868	561.2	.00259	.000586	.91016	553.9	.00064	.000146
42												
43	.93931	563.5	.00221	.000501	.93838	559.9	.00169	.000583	.94415	557.5	.00112	.000255
44	.93817	569.9	.00320	.000721	.93039	559.9	.00212	.000480	.92762	552.5	.00116	.00264
45	.93130	567.9	.00369	.000836	.92927	555.9	.00235	.000532	.91964	545.2	.00128	.000291
46	.93901	568.2	.00396	.000897	.92069	551.2	.00225	.000509	.91508	542.9	.00129	.000294
47	.93187	574.2	.00473	.001072	.92526	556.2	.00220	.000498	.91565	542.5	.00130	.000296
48	.92786	576.9	.00549	.001244	.91898	558.2	.00345	.000781	.90938	546.5	.00126	.000742
49	.92214	574.2	.00546	.001237	.91327	565.9	.00526	.001191	.90653	578.2	.00652	.001485
50	.92557	572.2	.00517	.001172	.91841	582.9	.00664	.001503	.92021	606.5	.01251	.002266
51	.92672	572.2	.00479	.001086	.92411	587.2	.00726	.001645	.93047	620.9	.01236	.002819
52	.92786	569.2	.00419	.000959	.92526	586.9	.00685	.001351	.93047	619.5	.01192	.002714
53	.93072	568.2	.00355	.000759	.94962	581.2	.00528	.001195	.93902	611.2	.00860	.001958
54												
55	.93359	566.5	.00323	.000732	.93667	578.5	.00441	.000998	.94358	593.2	.00742	.001690
56	.93015	564.2	.00318	.000721	.94811	579.9	.00555	.001256	.93560	562.9	.00965	.002197
57	.93416	560.2	.00227	.000511	.93324	571.5	.00374	.000818	.94016	583.5	.00573	.001305
58	.93187	565.5	.00318	.000721	.93552	580.2	.00478	.001082	.94244	600.9	.00790	.001799
59	.92898	570.5	.00439	.000995	.93438	588.9	.00674	.001526	.93902	621.5	.01152	.002623
60	.92443	574.9	.00571	.001294	.93495	566.2	.00767	.001736	.93674	623.2	.01529	.003482
61	.93416	563.2	.00273	.000619	.91784	551.9	.00221	.000500	.93275	592.9	.00136	.000310
62	.93015	565.5	.00366	.000829	.93210	574.9	.00430	.000973	.94529	605.2	.00691	.001574
63	.93015	571.9	.00455	.001031	.92868	555.9	.00196	.000441	.92933	551.9	.00141	.000321
64	.92901	574.2	.00508	.001151	.92583	561.2	.00327	.000740	.92648	548.2	.00116	.00264
65	.92557	569.9	.00487	.001104	.91955	584.2	.00693	.001569	.91756	605.5	.01028	.002311
66	.92500	569.2	.00456	.001033	.92468	585.2	.00701	.001587	.92104	619.9	.01236	.002815
67	.92557	565.2	.00393	.000891	.92526	583.2	.00690	.001471	.93275	617.9	.01153	.002626
68	.92301	562.5	.00275	.000623	.93210	574.9	.00430	.000973	.94529	605.2	.00691	.001574
69	.92786	576.2	.00544	.001235	.91442	568.9	.00497	.001122	.93032	568.5	.00593	.001145
70	.92385	566.2	.00438	.000995	.94012	571.9	.00514	.001163	.93686	578.5	.00679	.001546
71	.92901	572.2	.00475	.001076	.92640	581.5	.00599	.001356	.87220	544.5	.00451	.001027
72	.93015	560.2	.00265	.000996	.92868	564.5	.00316	.000715	.93032	541.5	.00219	.000499
73	.93187	559.9	.00188	.000426	.93153	560.2	.00215	.000487	.90141	538.9	.00188	.000428
74	.93359	563.5	.00276	.000625	.92868	563.2	.00292	.000661	.89616	532.9	.00154	.000351
75	.93416	563.5	.00268	.000607	.91613	553.2	.00238	.000539	.92554	544.2	.00058	.00132
76	.94675	559.2	.00127	.000289	.93438	551.9	.00109	.000247	.94301	556.5	.00108	.000246
77	.93072	561.5	.00277	.000628	.90472	547.2	.00268	.000607	.90539	532.9	.00078	.000178
78	.92786	563.5	.00353	.000800	.89502	543.2	.00292	.000661	.89331	532.2	.00174	.000396
79	.92500	565.2	.00397	.000900	.91042	543.5	.00182	.000412	.90072	533.2	.00130	.000296
80	.92672	566.9	.00420	.000952	.92069	549.5	.00157	.000378	.91508	541.9	.00096	.002129
81	.93187	574.2	.00490	.001110	.91670	553.5	.00305	.000690	.91394	547.2	.00286	.000651
82	.92786	576.2	.00506	.001147	.90700	563.2	.00496	.001123	.90368			

TABLE II.- HEAT-TRANSFER MEASUREMENTS AT $M = 3.51$ - Concluded(d) 18° Vortex Generator; $\phi = 0^\circ$

Thermocouple	T_e/T_t	$T_w, {}^\circ R$	$h, \text{Btu/sq ft-sec-}{}^\circ R$	N_{St}	T_e/T_t	$T_w, {}^\circ R$	$h, \text{Btu/sq ft-sec-}{}^\circ R$	N_{St}	T_e/T_t	$T_w, {}^\circ R$	$h, \text{Btu/sq ft-sec-}{}^\circ R$	N_{St}
$\alpha = 0^\circ; T_t = 698^\circ R; R = 3.49 \times 10^6$												
1	0.96972	650.2	0.00913	0.002055	0.97065	663.5	0.01738	0.003870	0.96466	669.8	0.01273	0.002873
2	0.90918	567.9	0.00517	0.001161	0.91468	580.9	0.00748	0.001666	0.91451	583.9	0.00812	0.001833
3	0.91260	556.9	0.00438	0.000986	0.90510	547.5	0.00422	0.000940	0.90539	553.2	0.00391	0.000883
4	0.92517	561.2	0.00393	0.000885	0.91488	548.5	0.00303	0.000675	0.91451	556.2	0.00317	0.000715
5	0.91603	554.3	0.00343	0.000772	0.90913	550.2	0.00408	0.000909	0.90482	536.9	0.00123	0.000278
6	0.92808	563.3	0.00352	0.000792	0.91488	545.2	0.00230	0.000510	0.92705	548.2	0.00098	0.000221
7	0.92688	566.9	0.00401	0.000903	0.91258	559.2	0.00198	0.000441	0.92363	543.2	0.00097	0.000219
8	0.92403	560.2	0.00379	0.000853	0.91258	556.5	0.00187	0.000416	0.92778	547.2	0.00140	0.000316
9	0.91260	557.9	0.00452	0.001017	0.90575	545.9	0.00368	0.000868	0.91565	554.2	0.00380	0.000888
10	0.91032	568.2	0.00512	0.001153	0.91145	575.5	0.00681	0.001517	0.91793	586.2	0.00824	0.001860
11	0.91203	556.9	0.00435	0.000975	0.92063	575.2	0.00778	0.001753	0.91361	611.9	0.01294	0.00291
12	0.92174	556.5	0.00350	0.000788	0.92983	583.2	0.00853	0.001858	0.92674	615.9	0.01322	0.00294
13	0.92574	564.9	0.00377	0.000849	0.93098	584.9	0.00847	0.001886	0.93731	614.2	0.01305	0.002945
14	0.92688	562.9	0.00343	0.000772	0.93388	581.5	0.00714	0.001590	0.94073	614.9	0.00985	0.002223
15	0.92517	560.9	0.00343	0.000772	0.92695	571.2	0.00559	0.001334	0.93275	595.2	0.00860	0.001941
16	0.92460	563.9	0.00382	0.000860	0.92523	572.9	0.00638	0.001421	0.92591	594.9	0.00939	0.002074
17	0.91375	557.2	0.00433	0.000975	0.91603	566.2	0.00703	0.001565	0.92021	585.9	0.00935	0.002110
18	0.93260	558.9	0.00232	0.000522	0.93388	551.5	0.00173	0.000985	0.91793	549.9	0.00191	0.000451
19	0.93374	564.2	0.00296	0.000666	0.93903	558.9	0.00220	0.001490	0.92078	544.5	0.00108	0.000244
20	0.93431	564.5	0.00282	0.000635	0.93388	557.5	0.00243	0.000514	0.92725	552.9	0.00099	0.000223
21	0.93202	560.2	0.00239	0.000538	0.92810	549.9	0.00206	0.000459	0.91304	552.9	0.00155	0.000350
22	0.93202	557.9	0.00215	0.000484	0.93388	565.5	0.00363	0.000808	0.93389	580.5	0.00443	0.001000
23	0.93317	562.9	0.00273	0.000615	0.93903	574.2	0.00471	0.001049	0.93920	590.5	0.00620	0.001399
24	0.93374	562.5	0.00266	0.000644	0.92695	569.2	0.00555	0.001236	0.92876	591.2	0.00796	0.001797
25	0.92917	567.9	0.00224	0.000504	0.92983	567.5	0.00435	0.000669	0.93617	590.5	0.00633	0.001429
26	0.91352	565.2	0.00188	0.001098	0.90513	556.5	0.00513	0.001209	0.91508	574.2	0.00640	0.001445
27	0.91317	566.2	0.00531	0.001195	0.90797	551.9	0.00513	0.00112	0.92850	569.5	0.00613	0.001341
28	0.93451	565.5	0.00312	0.000702	0.92293	551.9	0.00268	0.000597	0.92618	550.2	0.00181	0.000318
29	0.92346	563.2	0.00398	0.000696	0.90797	540.5	0.00244	0.000543	0.91565	546.2	0.00159	0.000361
30	0.91774	565.2	0.00505	0.001157	0.90797	542.9	0.00268	0.000641	0.91594	554.5	0.00314	0.000709
31	0.91546	568.2	0.00547	0.001231	0.90855	552.2	0.00464	0.001353	0.91166	567.2	0.00582	0.001314
32	0.92005	567.5	0.00507	0.001141	0.91373	574.9	0.00665	0.001476	0.92078	581.2	0.00905	0.002055
33	0.92289	563.2	0.00403	0.000907	0.92005	574.2	0.00734	0.001655	0.92762	569.9	0.01054	0.002379
34	0.92574	560.2	0.00310	0.000698	0.92408	568.5	0.00564	0.001256	0.93218	590.9	0.00749	0.001651
35	0.91774	566.9	0.00559	0.001258	0.92580	565.2	0.00495	0.001102	0.89172	546.2	0.00377	0.000851
36	0.92403	561.5	0.00354	0.000797	0.92929	562.0	0.00433	0.000964	0.91565	544.2	0.00125	0.000282
37	0.92917	561.5	0.00303	0.000750	0.93731	563.5	0.00328	0.000730	0.92306	555.2	0.00209	0.000472
38	0.93202	562.2	0.00195	0.000439	0.93501	551.5	0.00211	0.000470	0.91964	560.5	0.00191	0.000451
39	0.92574	568.9	0.00500	0.000675	0.93388	556.2	0.00250	0.000557	0.93324	540.5	0.00204	0.000460
40	0.92803	559.9	0.00298	0.000671	0.91430	546.2	0.00258	0.000757	0.90710	537.9	0.00109	0.000246
41	0.93031	559.9	0.00263	0.000592	0.92120	548.5	0.00226	0.000503	0.92365	543.9	0.00087	0.000151
42	0.93260	560.2	0.00233	0.000521	0.92753	550.5	0.00202	0.000450	0.92990	547.9	0.00065	0.000147
43	0.93374	557.5	0.00200	0.000450	0.93098	549.5	0.00180	0.000401	0.93047	552.9	0.00106	0.000239
44	0.93202	562.9	0.00285	0.000612	0.92178	549.5	0.00227	0.000506	0.91964	541.5	0.00073	0.000165
45	0.92588	561.5	0.00333	0.000750	0.91315	544.5	0.00291	0.000559	0.91166	539.9	0.00118	0.000266
46	0.92531	562.5	0.00353	0.000750	0.91835	544.5	0.00236	0.000526	0.90824	540.2	0.00136	0.000307
47	0.92531	566.3	0.00124	0.000951	0.91835	544.5	0.00216	0.000481	0.90938	540.9	0.00156	0.000352
48	0.92346	569.2	0.00515	0.001150	0.91488	547.2	0.00316	0.000700	0.90938	544.9	0.00251	0.000567
49	0.91946	569.3	0.00552	0.001243	0.91085	554.5	0.00475	0.001058	0.90767	561.9	0.00515	0.001162
50	0.91946	565.2	0.00509	0.001146	0.91545	567.2	0.00620	0.001381	0.91907	588.5	0.00863	0.001968
51	0.92460	565.9	0.00425	0.000957	0.92293	572.9	0.00720	0.001603	0.92876	562.2	0.01104	0.002492
52	0.92651	564.2	0.00377	0.000649	0.92465	575.2	0.00684	0.001528	0.92876	561.2	0.00988	0.002230
53	0.92803	561.2	0.00297	0.000669	0.92925	565.9	0.00525	0.001169	0.93731	571.2	0.00689	0.001555
54	0.93202	556.5	0.00198	0.000446	0.93040	556.9	0.00302	0.000673	0.93332	574.2	0.00592	0.000885
55	0.92860	559.9	0.00282	0.000635	0.94706	569.2	0.00411	0.000915	0.94643	590.5	0.00610	0.001377
56	0.92688	558.5	0.00281	0.000633	0.93040	571.9	0.00575	0.001280	0.93503	597.5	0.00860	0.001941
57	0.93145	558.5	0.00197	0.000443	0.93388	563.2	0.00375	0.000835	0.93788	580.9	0.00536	0.001210
58	0.92917	560.5	0.00287	0.000646	0.93271	566.9	0.00461	0.001027	0.93446	584.5	0.00634	0.001451
59	0.92403	562.2	0.00389	0.000876	0.92325	569.5	0.00658	0.001465	0.91850	587.2	0.00937	0.002115
60	0.91260	560.2	0.00495	0.001114	0.90510	561.9	0.00763	0.001699	0.90565	576.9	0.00938	0.002117
61	0.93145	558.9	0.00237	0.000533	0.90222	536.2	0.00223	0.000497	0.91451	539.2	0.00884	0.000190
62	0.92574	561.2	0.00336	0.000756	0.93271	554.5	0.00195	0.000434	0.90141	538.5	0.00214	0.000483
63	0.92588	566.5	0.00431	0.000716	0.91085	539.5	0.00475	0.000666	0.91066	545.9	0.00238	0.000537
64	0.92160	569.9	0.00520	0.001171	0.91200	544.9	0.00299	0.000659	0.91468	585.5	0.00794	0.001792
65	0.91889	563.9	0.00478	0.001076	0.90797	563.9	0.00659	0.000675	0.91622	585.5	0.01030	0.00293
66	0.92117	562.5	0.00417	0.000939	0.91603	570.2	0.00738	0.001643	0.92648	560.5	0.01054	0.002402
67	0.92346	560.5	0.00350	0.000788	0.91718	569.9	0.00697	0.001552	0.92591	594.9	0.00948	0.002140
68	0.92917	557.9	0.00247	0.000556	0.92925	562.5	0.00430	0.000958	0.93599	582.5	0.00538	0.001214
69	0.91660	563.2	0.00187	0.000748	0.90222	561.2	0.00541	0.001205	0.90913	547.2	0.00341	0.000770
70	0.92289	561.2	0.00395	0.000889	0.92235	560.5	0.00444	0.000899	0.90482	558.5	0.00318	0.000511
71	0.92403	563.9	0.00422	0.000530	0.92400	563.5	0.00417	0.000293	0.90312	542.5	0.00228	0.000515
72	0.92917	556.9	0.00236	0.000531	0.92983	557.2	0.00303	0.000675	0.92648	550.5	0.00380	0.000737
73												

TABLE III.- HEAT-TRANSFER MEASUREMENTS AT $M = 4.50$ FOR 13° VORTEX GENERATOR; $\phi = 0^\circ$

Thermocouple	T _e /T _t	T _w , °R	h, Btu/sq ft-sec-°R	N _{St}	T _e /T _t	T _w , °R	h, Btu/sq ft-sec-°R	N _{St}	T _e /T _t	T _w , °R	h, Btu/sq ft-sec-°R	N _{St}
	$\alpha = 0^\circ$; T _t = 682° R; R = 4.07×10^6						$\alpha = 8^\circ$; T _t = 679° R; R = 4.06×10^6					
1	0.95378	636.2	0.01243	0.003586	0.96585	645.5	0.01886	0.005453	0.90399	566.2	0.00710	0.002033
2	.90351	560.2	.00389	.001122	.89757	557.2	.00484	.001399	.90568	547.9	.00322	.000922
3	.91025	556.5	.00283	.000811	.90589	551.5	.00215	.000622	.92193	555.5	.00327	.000936
4	.92034	558.5	.00221	.000638	.91884	554.2	.00166	.000480	.91472	546.5	.00182	.000521
5	.92427	561.2	.00200	.000577	.92444	557.2	.00144	.000416	.92150	547.5	.00104	.000298
6												
7	.92539	562.9	.00217	.000626	.92052	552.9	.00117	.000358	.93392	554.5	.00093	.000266
8	.92146	559.5	.00223	.000643	.91828	552.2	.00135	.000390	.92940	553.5	.00123	.000352
9	.91193	556.9	.00281	.000811	.91269	553.9	.00250	.000723	.92193	555.5	.00327	.000936
10	.90856	561.2	.00364	.001050	.91157	565.7	.00159	.001327	.92206	570.9	.00805	.002305
11	.91193	557.2	.00292	.000814	.92052	572.2	.00567	.001639	.93279	596.5	.01253	.003588
12	.92315	561.2	.00236	.000681	.92780	579.2	.00643	.001859	.93997	595.2	.01363	.004553
13	.92539	564.2	.00236	.000681	.92948	578.0	.00602	.001741	.94552	594.5	.01274	.003648
14												
15	.91866	558.2	.00199	.000577	.92166	568.9	.00456	.001318	.93279	581.9	.00974	.002789
16	.91417	554.9	.00207	.000597	.92106	567.2	.00457	.001264	.92957	578.9	.00969	.002775
17	.90747	554.9	.00286	.000825	.91269	564.2	.00519	.001501	.92432	574.5	.00996	.002852
18	.93268	562.9	.00134	.000587	.94101	564.5	.00900	.000260	.93449	556.2	.00101	.000289
19	.93941	569.5	.00185	.000534	.94683	567.9	.0085	.000246	.94691	563.9	.00886	.002416
20	.93941	569.5	.00181	.000522	.93507	558.9	.00666	.001919	.96917	563.2	.00880	.00229
21	.93437	565.9	.00168	.000485	.92444	557.2	.00138	.000399	.94409	562.5	.00122	.000349
22	.93437	564.5	.00151	.000436	.93060	566.9	.00213	.000616	.94465	577.2	.00415	.001188
23	.93829	570.2	.00171	.000493	.93787	576.2	.00298	.000862	.94465	582.2	.00525	.001503
24	.93889	568.5	.00188	.000542	.92658	569.5	.00399	.001154	.93336	579.9	.00856	.002451
25	.92763	562.2	.00145	.000418	.92668	571.9	.00316	.000914	.94013	568.9	.00718	.002056
26	.91137	561.2	.00374	.001079	.91269	559.5	.00363	.001050	.92545	568.2	.00582	.001667
27	.91025	563.2	.00411	.001186	.91213	558.9	.00366	.001058	.92206	565.5	.00577	.001652
28	.93212	566.5	.00217	.000626	.92948	560.9	.0149	.000431	.94860	564.2	.00805	.002413
29	.92315	563.5	.00282	.000814	.91716	559.2	.00222	.000353	.93731	556.5	.00999	.002833
30	.91922	564.2	.00342	.000987	.91380	552.2	.00206	.000596	.92601	559.2	.00261	.000747
31	.91754	565.9	.00365	.001053	.90933	556.9	.00360	.001011	.92037	570.2	.00575	.001547
32	.91922	564.5	.00337	.000972	.91269	566.9	.00509	.001472	.92711	562.9	.01231	.003525
33	.92090	562.9	.00288	.000831	.91772	571.5	.00594	.001717	.93505	568.9	.01288	.003688
34	.92259	560.9	.00224	.000646	.92500	569.9	.00419	.001212	.94409	564.5	.00761	.002179
35	.91842	564.2	.00538	.001033	.92052	560.9	.00260	.000752	.92376	555.2	.00227	.000650
36	.91978	560.9	.00240	.000692	.91716	557.9	.00243	.000703	.91529	546.5	.00101	.000289
37	.92599	562.2	.00213	.000515	.93287	564.5	.00190	.000549	.94013	561.2	.00143	.000409
38	.93156	560.9	.00132	.000381	.93171	560.9	.00127	.000367	.92884	552.9	.00096	.000275
39	.92820	562.2	.00185	.000534	.92948	558.9	.00121	.000350	.92376	550.5	.00128	.000367
40	.92820	563.2	.00205	.000591	.92724	559.5	.00150	.000434	.94013	555.9	.00047	.000135
41	.92988	563.9	.00185	.000534	.93283	559.5	.00089	.000257	.95143	561.5	.00028	.000080
42												
43	.93268	562.9	.00143	.000413	.93787	561.9	.00803	.002440	.95538	565.9	.00085	.000243
44	.93100	565.2	.00203	.000586	.92612	557.9	.00136	.000393	.95143	562.9	.00054	.000155
45	.92539	562.5	.00231	.000675	.91772	552.9	.0140	.000405	.95222	559.5	.00056	.000160
46	.92315	562.2	.00248	.000716	.91436	550.2	.00132	.000382	.94013	557.2	.00076	.000218
47	.92315	564.9	.00294	.000848	.91604	549.5	.00093	.000269	.93618	566.2	.00100	.000286
48												
49	.91193	561.9	.00355	.001024	.90533	555.2	.00339	.000980	.91754	561.2	.00521	.001492
50	.91810	564.2	.00342	.000987	.90765	564.9	.00518	.001498	.92027	562.9	.00521	.001492
51	.92315	565.2	.00300	.000866	.91884	571.9	.00584	.001689	.93336	589.2	.01322	.003786
52	.92595	564.9	.00257	.000714	.92332	574.2	.00553	.001599	.93900	589.2	.01133	.003244
53	.92651	562.9	.00208	.000600	.93115	572.5	.00590	.001228	.94973	587.2	.00722	.002067
54	.93156	561.9	.00141	.000405	.93619	567.9	.00194	.000561	.95312	578.9	.00354	.001014
55	.93100	564.2	.00197	.000568	.93955	573.2	.00290	.000839	.95595	587.2	.00619	.001773
56	.92820	562.2	.00198	.000591	.92948	572.5	.00421	.001217	.93900	585.5	.01001	.002866
57	.92932	560.2	.00140	.000404	.91604	560.9	.00318	.000404	.94070	575.5	.00558	.001598
58												
59	.92427	564.5	.00276	.000796	.91828	566.5	.00465	.001345	.92545	574.9	.00945	.002706
60	.91922	565.2	.00342	.000987	.89534	554.5	.00542	.001567	.92376	573.2	.00965	.002763
61	.92763	560.5	.00163	.000470	.92500	554.5	.00107	.000309	.94860	560.5	.00045	.000129
62	.92259	560.9	.00223	.000616	.91884	551.9	.00114	.000350	.93957	557.9	.00088	.000252
63	.91698	560.5	.00271	.000791	.92220	552.9	.00089	.000257	.93223	554.5	.00099	.000283
64	.91137	557.9	.00303	.000874	.91828	553.9	.00182	.000526	.92489	553.5	.00229	.000656
65	.91081	558.5	.00308	.000889	.91213	564.5	.00483	.001397	.92037	574.9	.01048	.002984
66	.92034	562.9	.00291	.000804	.91940	570.9	.00505	.001590	.93053	586.2	.01308	.003746
67	.92371	562.2	.00244	.000704	.92388	576.2	.00507	.001466	.93279	584.2	.01089	.003118
68	.92876	561.2	.00158	.000456	.93563	570.2	.00280	.000810	.95199	582.5	.00538	.001541
69	.92146	564.9	.00304	.000877	.91501	560.9	.00318	.001006	.92930	574.2	.00276	.000790
70	.91922	560.5	.00255	.000736	.91884	558.5	.00253	.000752	.94546	559.2	.00123	.000352
71	.92315	564.9	.00161	.000837	.92658	564.5	.00265	.000760	.93957	559.5	.00123	.000352
72	.92651	559.5	.00161	.000464	.92596	558.5	.00157	.000454	.92884	549.9	.00051	.000146
73	.93381	561.2	.00116	.000355	.92444	559.5	.00114	.000350	.93674	554.2	.00048	.00137
74	.93156	562.2	.00146	.000421	.91716	551.9	.00126	.000370	.93392	552.2	.00057	.001663
75	.93212	562.9	.00154	.000444	.92388	553.9	.00073	.000211	.94973	560.5	.00026	.000808
76	.93324	561.2	.00108	.000312	.93843	561.2	.00071	.000205	.95482	565.2	.00064	.000183
77	.92539	558.9	.00153	.000441	.91716	568.2	.00080	.000231	.94013	555.2	.00041	.000117
78	.92034	558.2	.00206	.000594	.90261	543.2	.00127	.000367	.92997	550.9	.00077	.000220
79	.91292	557.5	.00236	.000681	.90737	541.5	.00092	.000266	.92150	549.2	.00132	.000378
80	.91586	557.2	.00234	.000675	.91101	545.2	.00079	.000228	.91924	547.2	.00107	.000306
81	.92034	561.5	.00265	.000765	.90709	546.9	.00168	.000486	.91529	547.2	.00194	.000556
82	.91810	564.2	.00308	.000889	.89895	549.2	.00317	.000917	.90794	552.5	.00464	.001329
83	.92090	563.5	.00277	.000799	.90373	558.2	.00437	.001264	.91529	576.5	.00813	.002414
84	.91642	558.9	.00265	.000765	.91213	564.5	.00497	.001437	.92658	581.2	.01179	.003376
85	.91754	559.5	.00259	.000747	.91716	568.2	.00521	.001506	.92601	581.5	.01211	.003468
8												

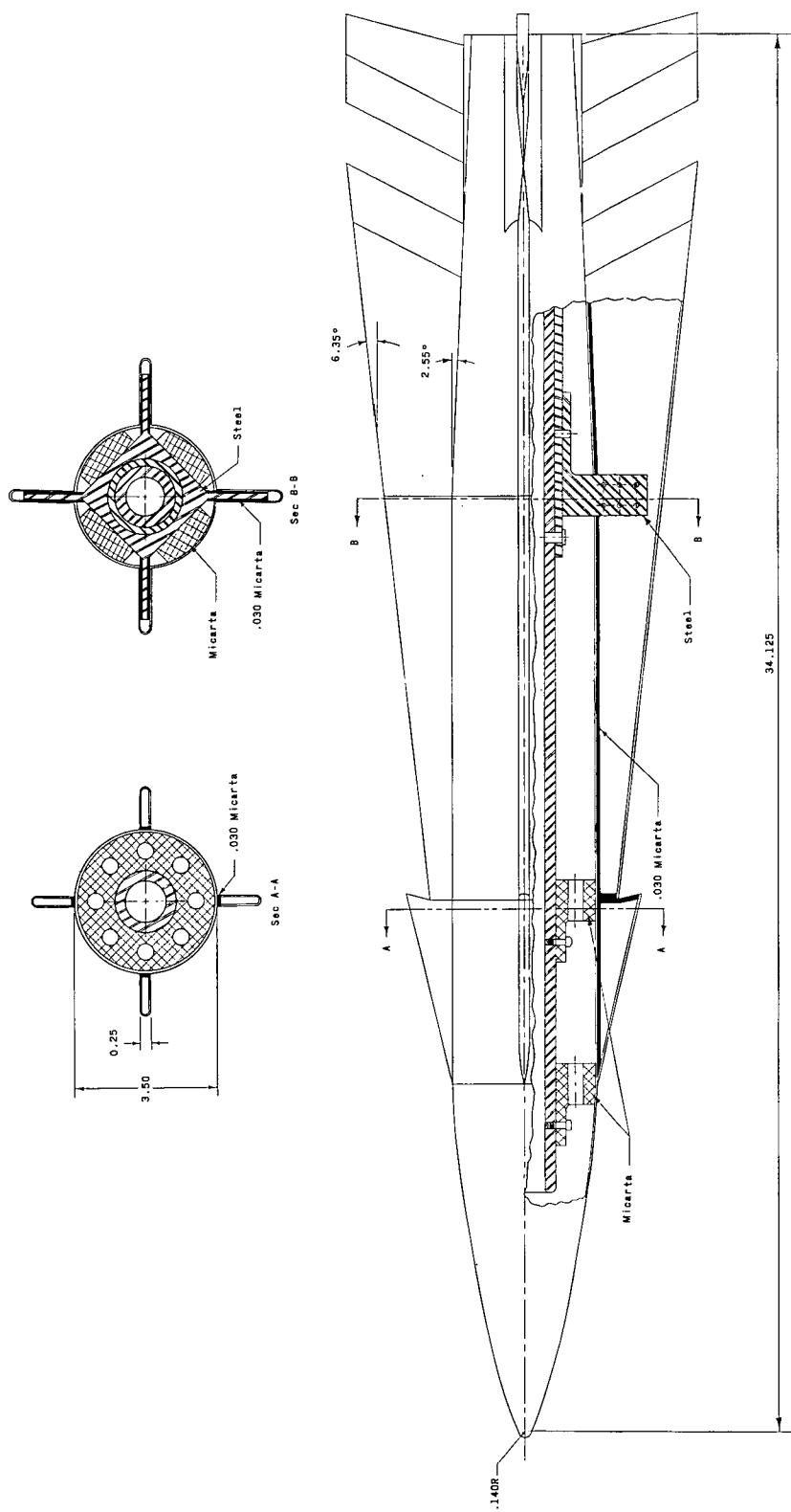


Figure 1.- Geometric characteristics and construction techniques. Dimensions are in inches.

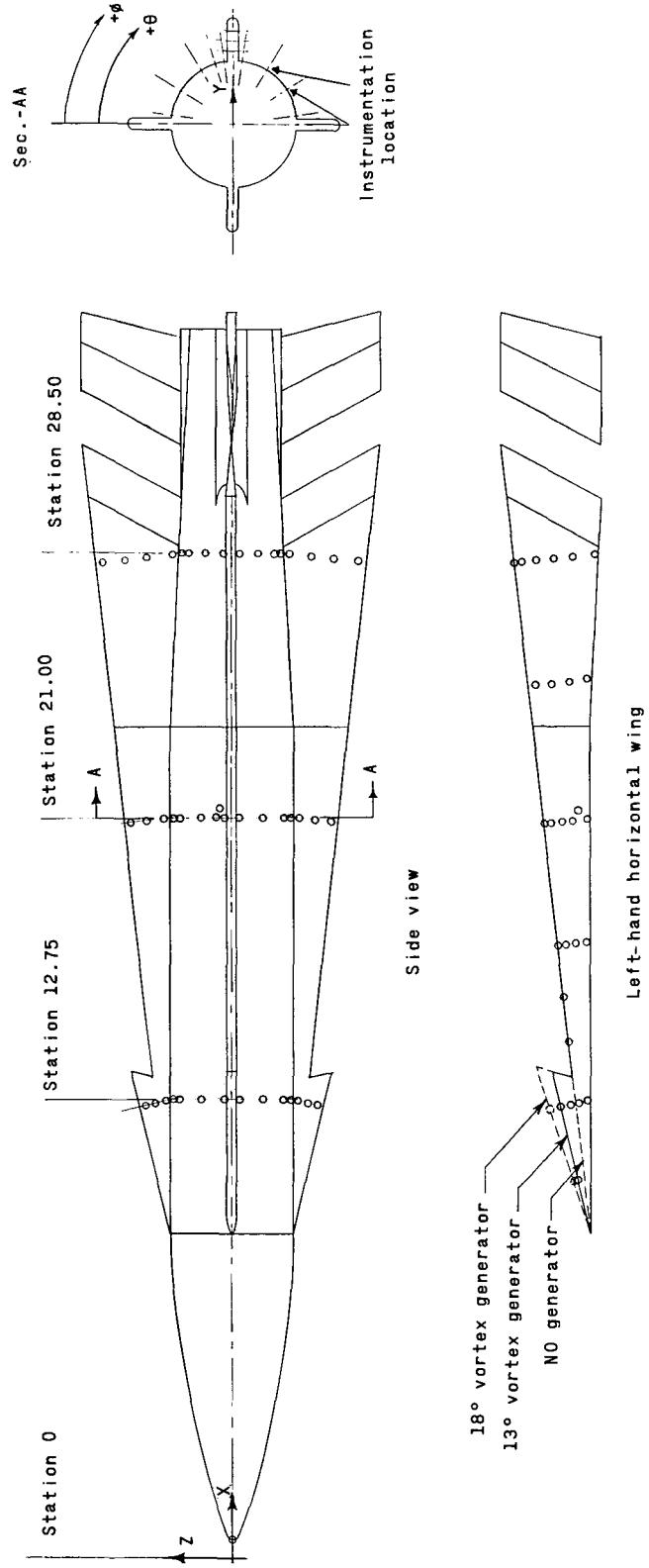
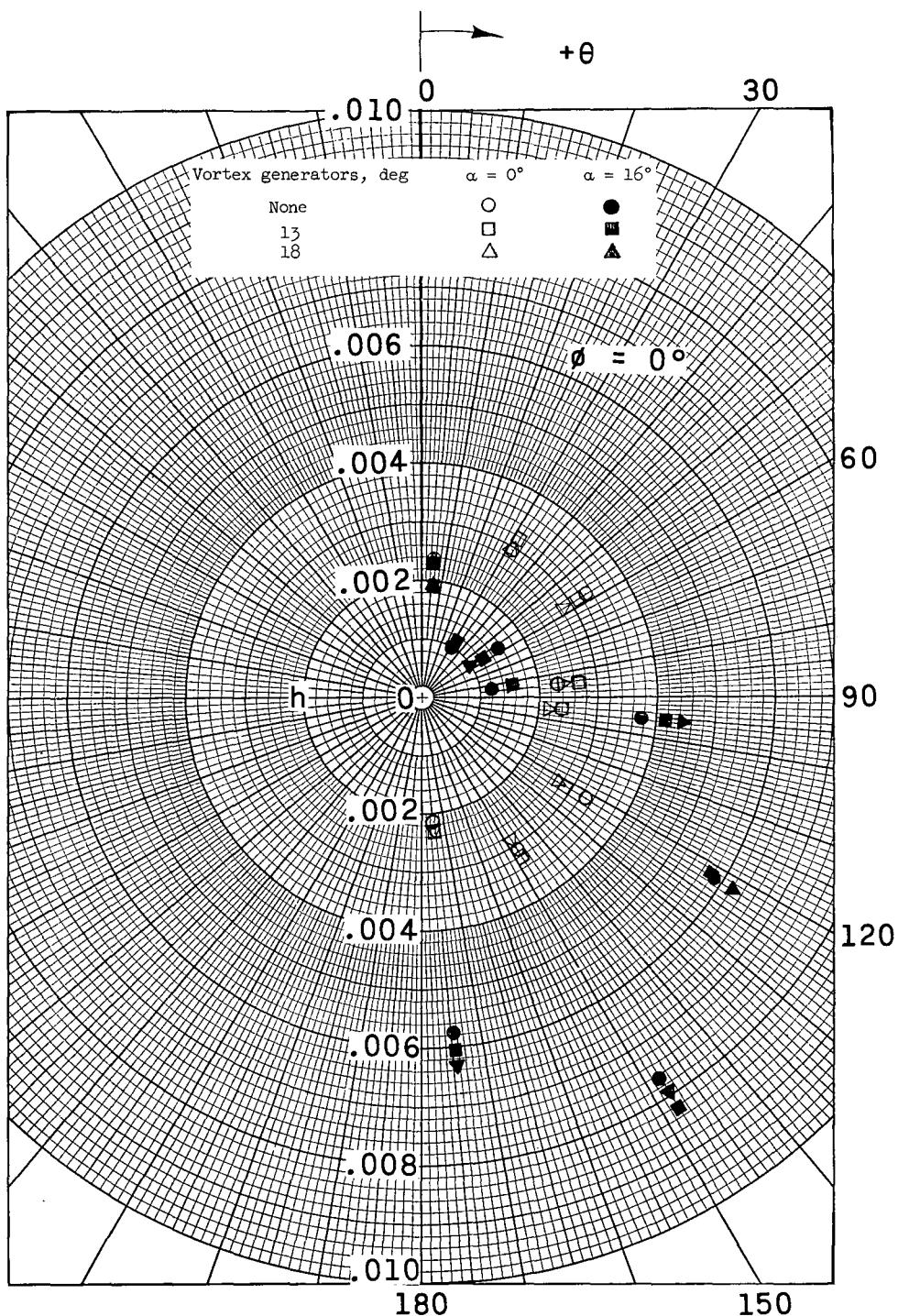
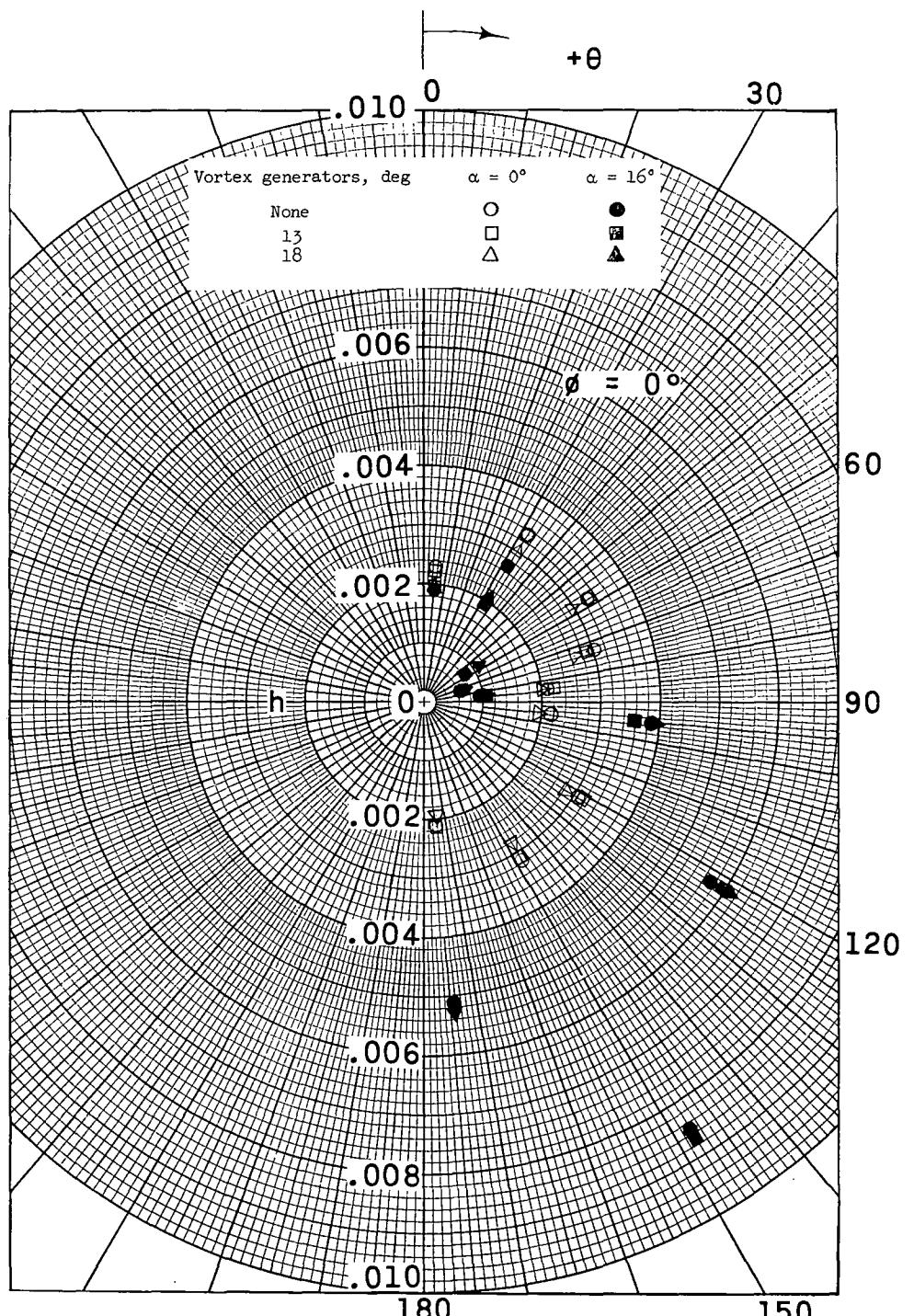


Figure 2.- View showing thermocouple locations.



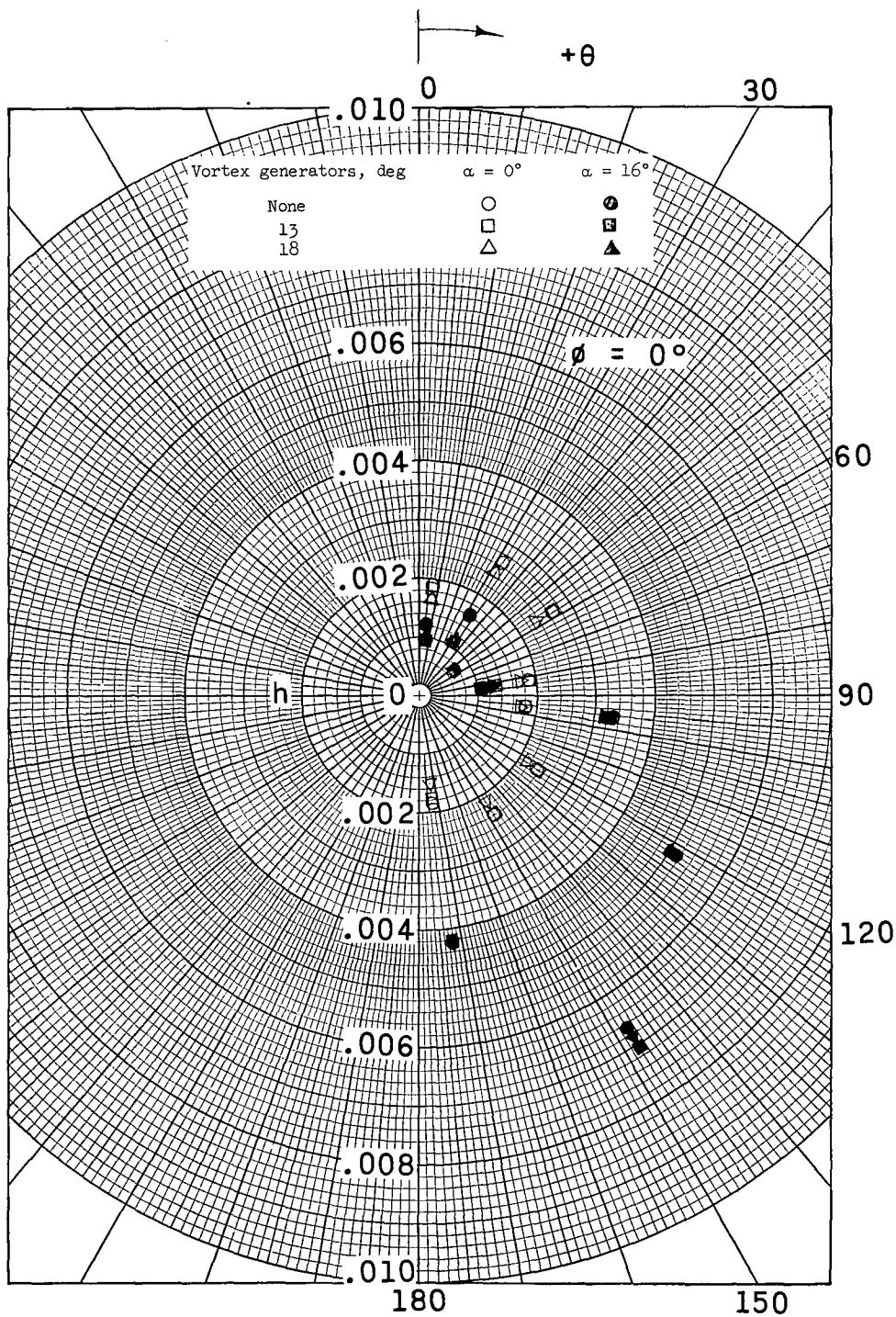
(a) Station 12.75.

Figure 3.-- Effect of vortex generators on the circumferential distribution of heat-transfer coefficients. $M = 3.51$.



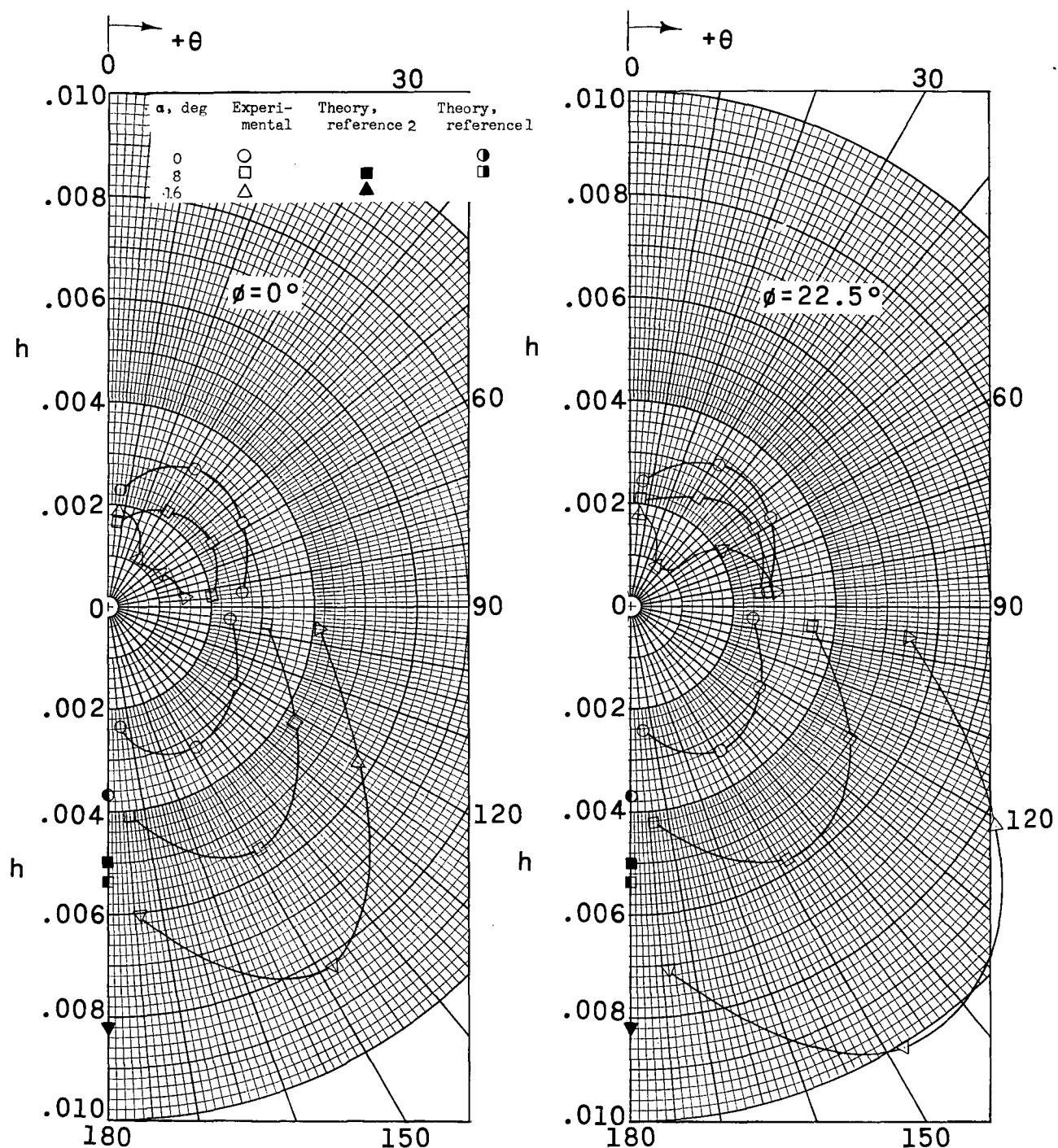
(b) Station 21.0.

Figure 3.- Continued.



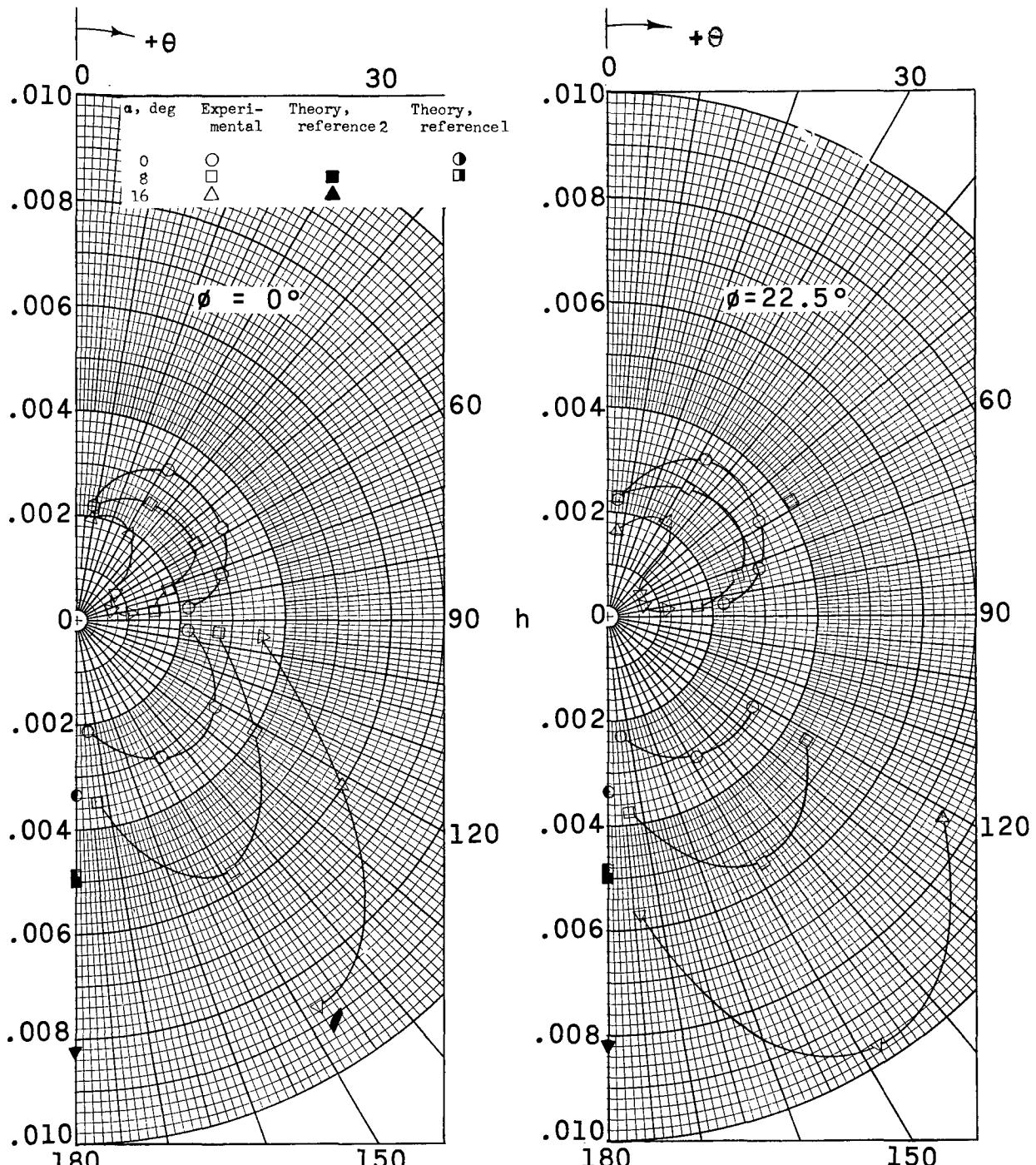
(c) Station 28.5.

Figure 3.- Concluded.



(a) Station 12.75.

Figure 4.- Effect of angle of attack on the circumferential distribution of heat-transfer coefficients. $M = 3.51$.



(b) Station 21.0.

Figure 4--Continued.

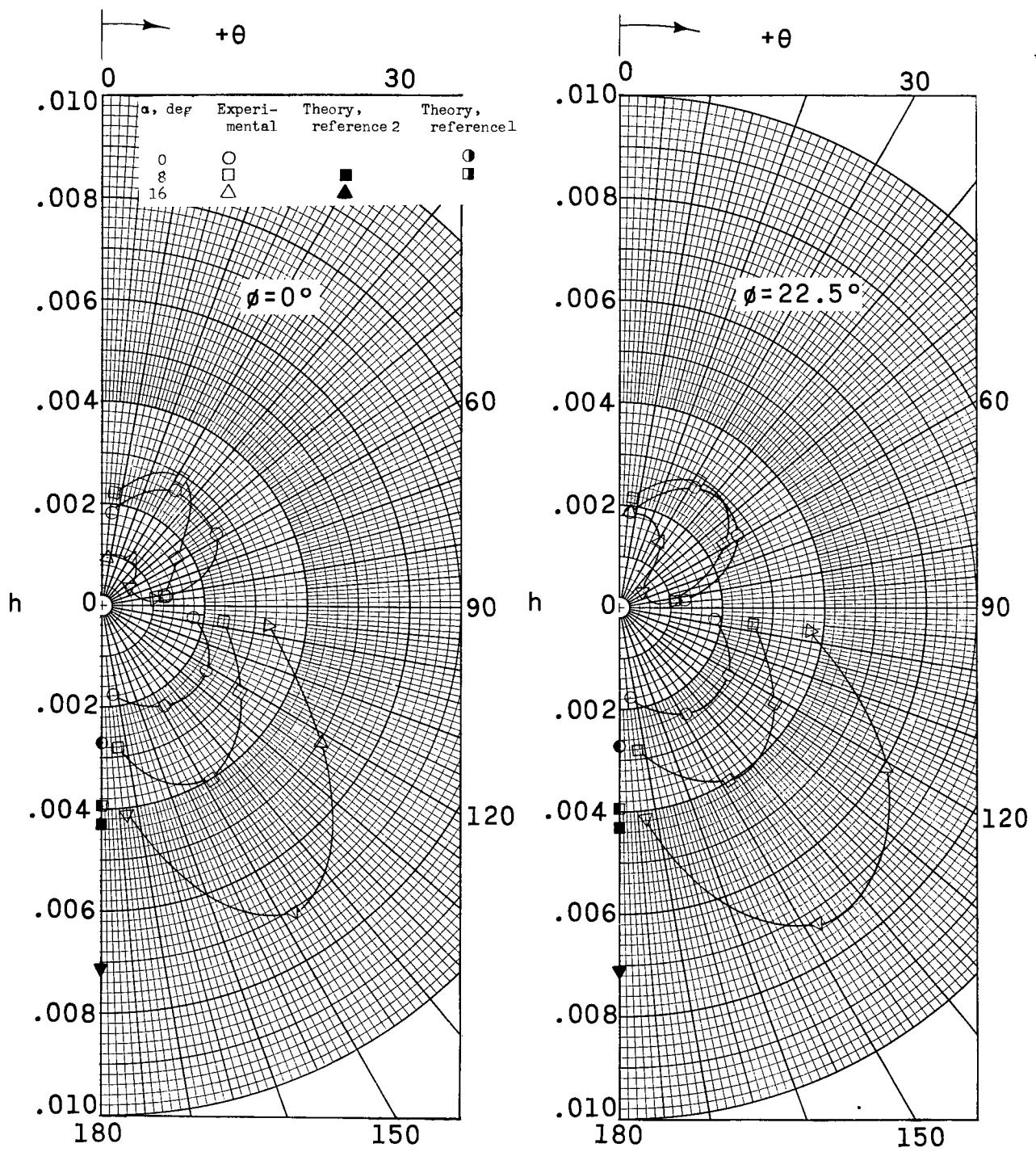
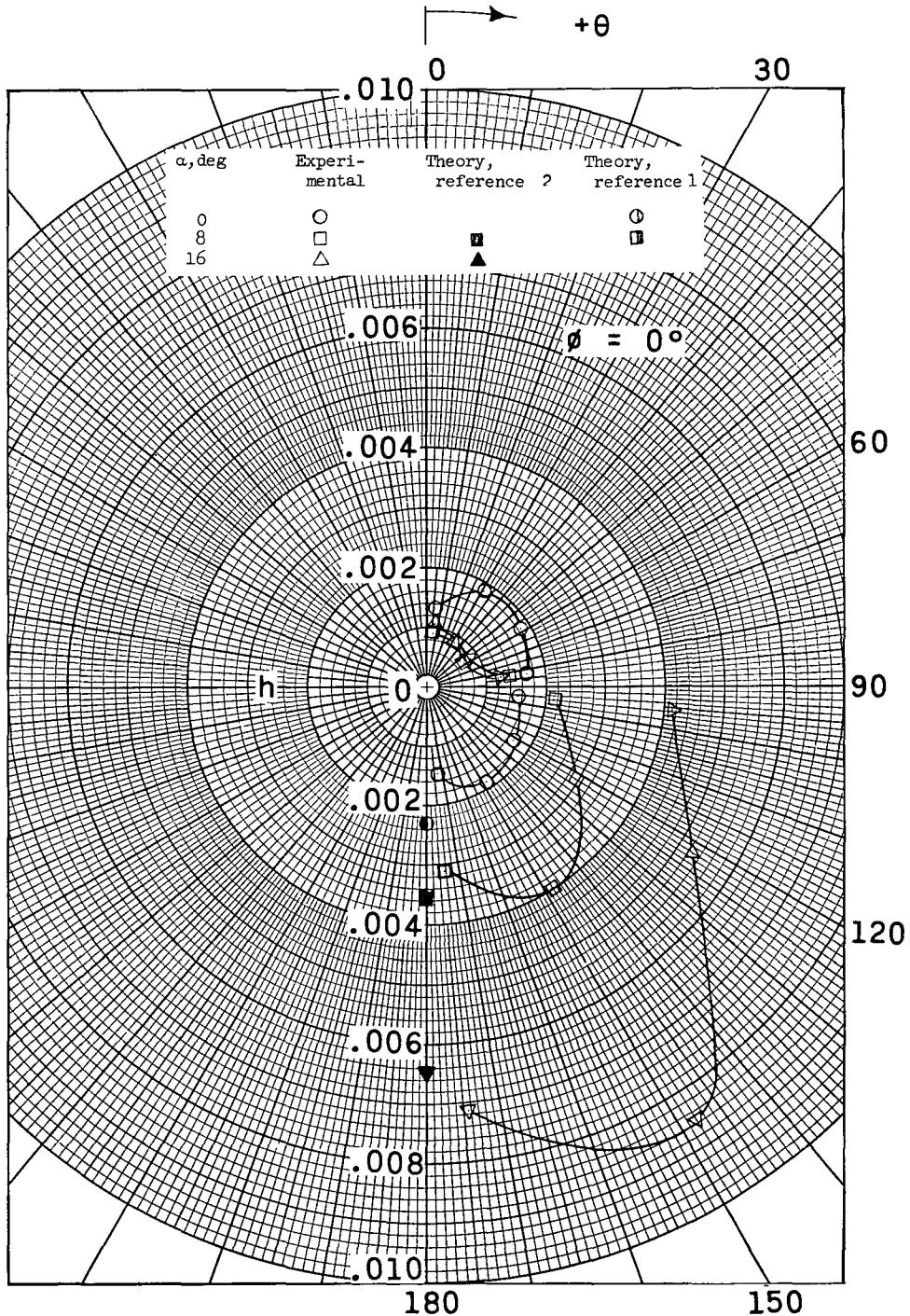
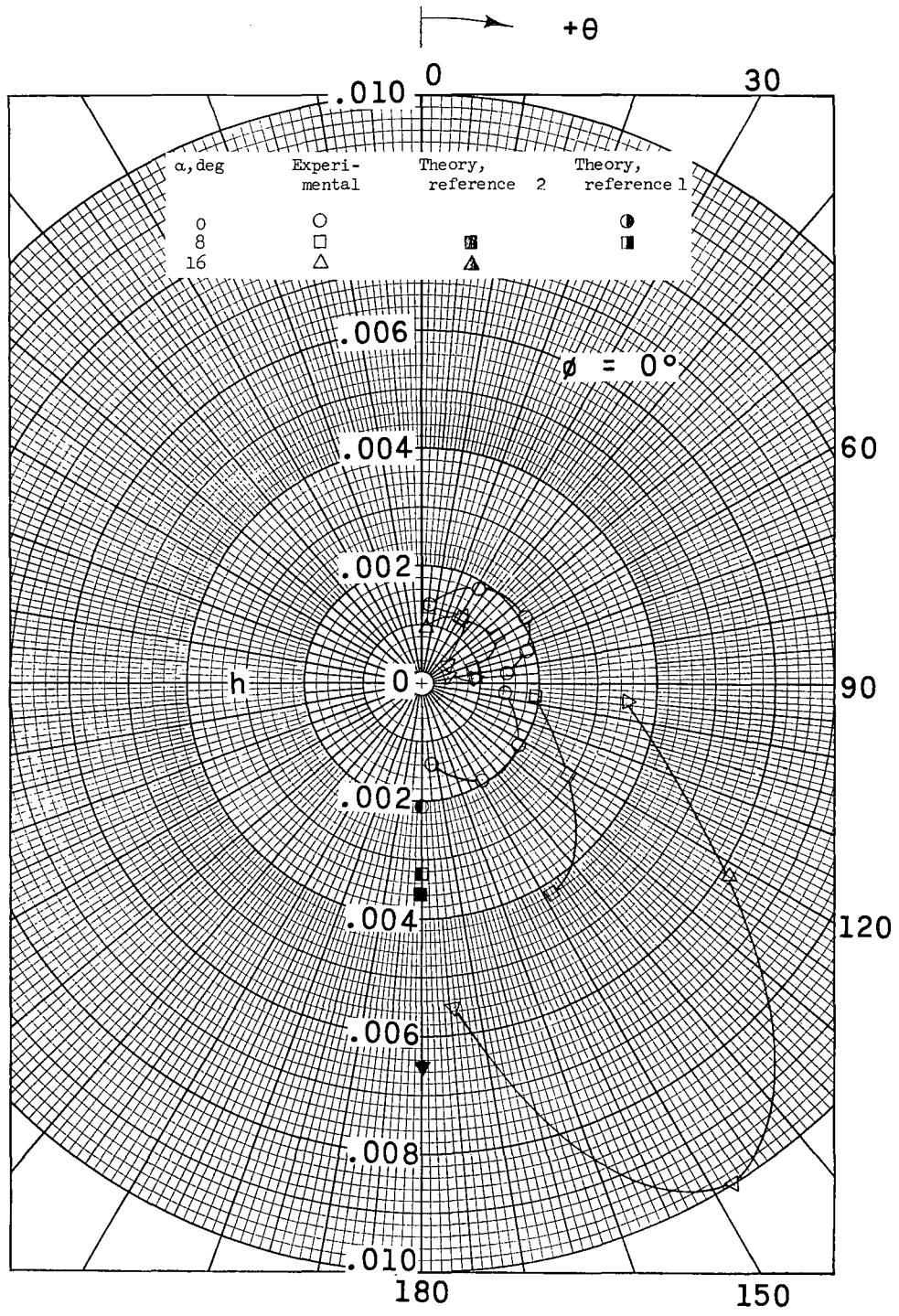


Figure 4.- Concluded.



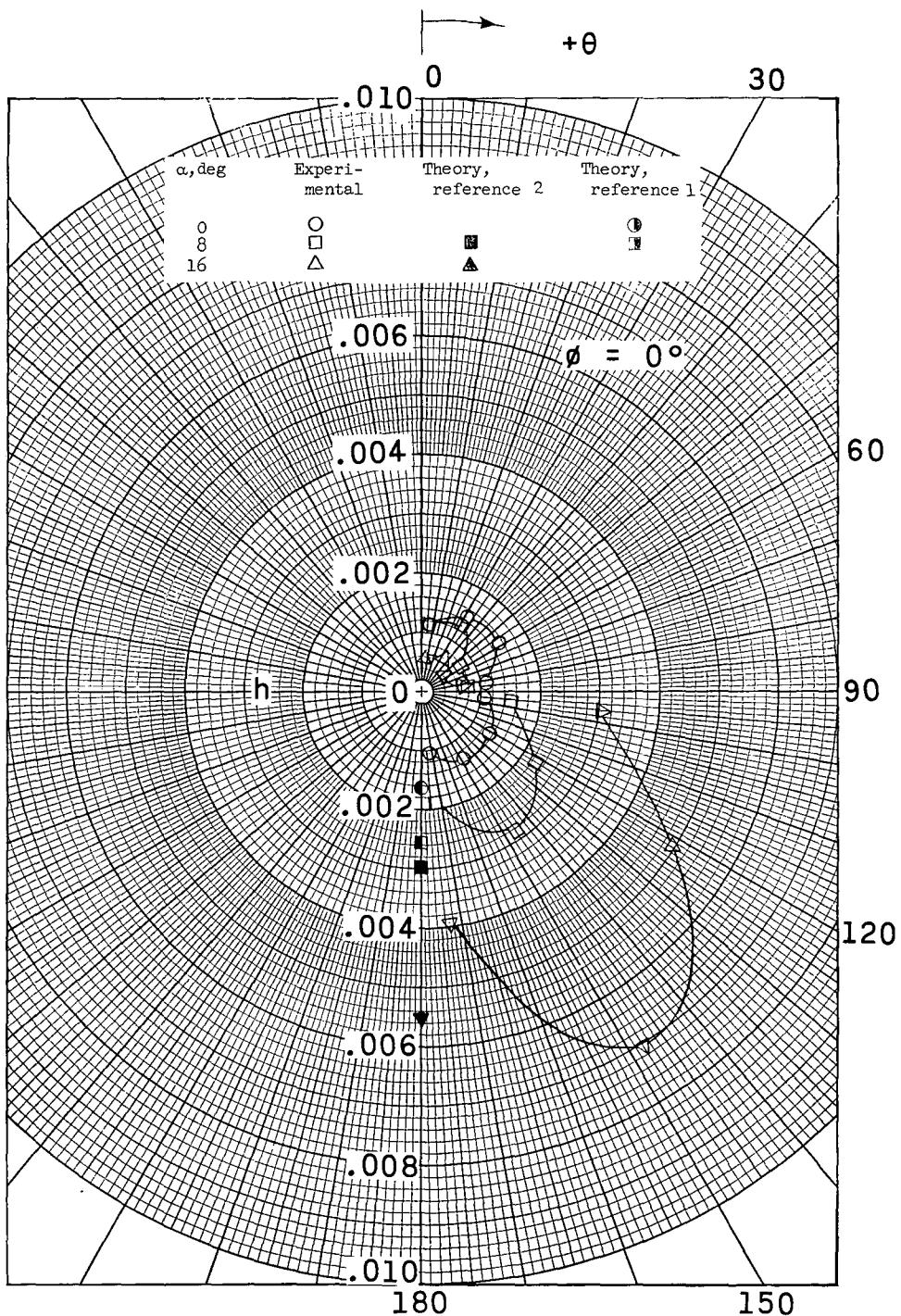
(a) Station 12.75.

Figure 5.- Effect of angle of attack on the circumferential distribution of heat-transfer coefficients. $M = 4.50$.



(b) Station 21.0.

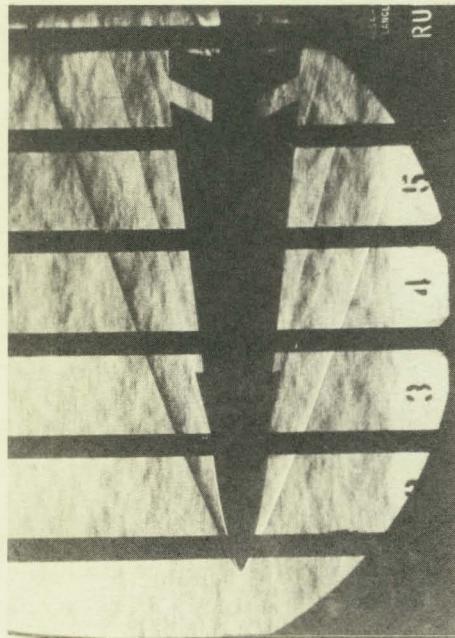
Figure 5.- Continued.



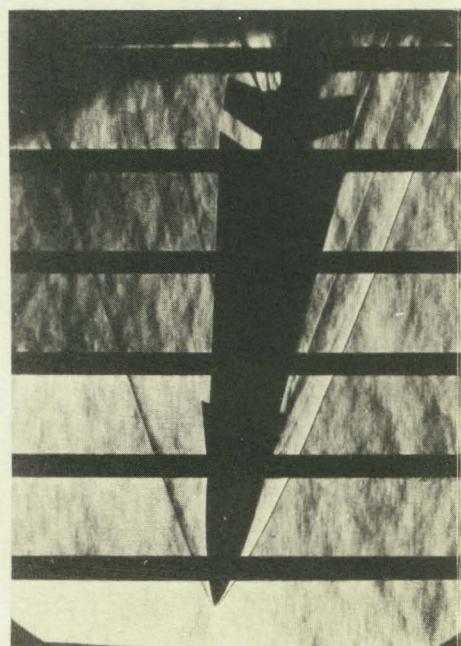
(c) Station 28.5.

Figure 5-- Concluded.

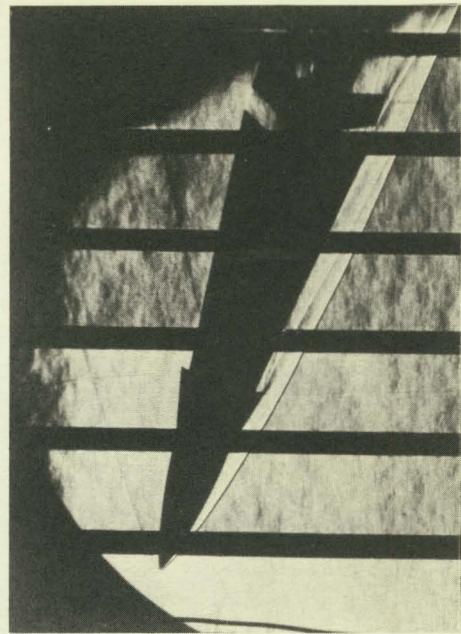
~~CONFIDENTIAL~~



$\alpha = 0^\circ$



$\alpha = 8^\circ$



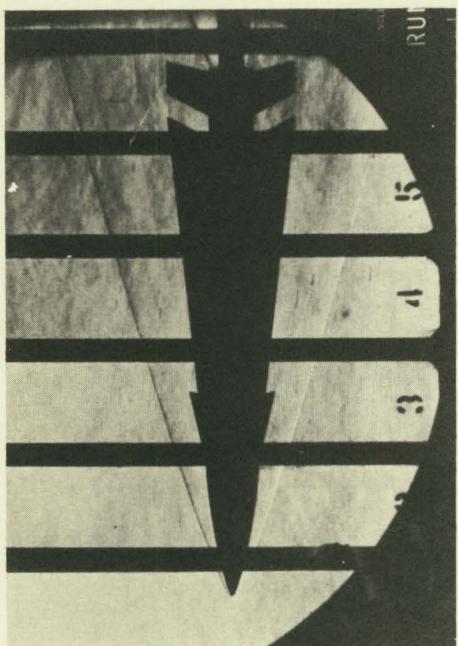
$\alpha = 16^\circ$

(a) $M = 3.50$.

L-63-3151

Figure 6.- Schlieren photographs of the 15° vortex-generator configuration.

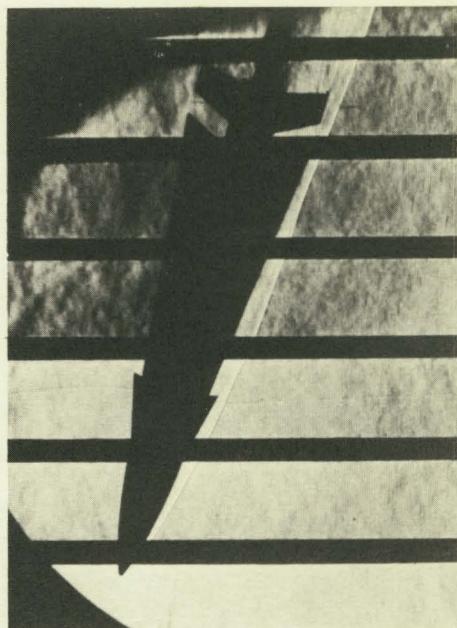
~~CONFIDENTIAL~~



$\alpha = 0^\circ$



$\alpha = 8^\circ$



$\alpha = 16^\circ$

(b) $M = 4.50$.

Figure 6.- Concluded.

L-63-3152